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Bulletin No. 356 February 1939

Field Corn in Massachusetts

By William G. Colby and Ralph W. Donaldson

This study was undertaken to determine the climatic adaptation of a large number of hybrid and open-pollinated corn varieties and also to review the necessary practices for successful corn culture in this State.

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FIELD CORN IN MASSACHUSETTS

By William G. Colby, Research Professor of Agronomy,

and Ralph W. Donaldson, Extension Agronomist

Massachusetts lies too near the northern limit of the successful corn growing area to mature grain of the late, heavy-yielding varieties of the Corn Belt. Yet corn is so well adapted to our soils when fertilized, and suitable varieties produce so much cattle feed to the acre, that most livestock farmers grow it. Moreover, corn is a useful tilled crop when refitting sod land in preparation for reseeding.

Of approximately 40,000 acres of field corn grown in the State, about 24,000 acres are ensiled, 10,000 acres are husked for grain, and 6,000 acres are fed green.

An estimate of the relative acre-yield of corn and nutrients it contains compared with that of other common feed crops is given in the following table, based on average yields[1] for the State recorded in 1937.

TABLE 1.--AVERAGE YIELD AND FEEDING VALUE OF CORN COMPARED WITH OTHER FIELD CROPS

Crop	Average Yields per Acre	Pounds of Digestible Nutrients* per Acre	
		Protein	Total
Corn Silage	11.5 tons	300	4,300
Alfalfa Hay	2.25 tons	477	2,266
Clover Hay	2.0 tons	280	2,076
Grass Hay	1.5 tons	105	1,551
Oats Hay	2.0 tons	180	1,852
Corn Grain	41.0 bushels	170	1,930
Oats Grain	30.0 bushels	90	686

*Morrison's "Feeds and Feeding."

On the basis of average yields, corn grown for silage far excels other common crops in the amount of total digestible nutrients produced, although alfalfa may furnish more protein. Moreover, when grown for grain, corn furnishes almost twice as much protein as oats and nearly three times as much digestible nutrients. In addition, the by-product stover is worth more than oat straw as feed.

Although corn is capable of big yields where soil and climate are favorable, its productiveness is seriously impaired on heavy wet land or where late spring and early fall frosts reduce the length of growing season. Under such conditions, oats or some other short-season crop may well prove more practical in the sod rotation.

Labor is a considerable item in the production of corn, and silage making requires expensive equipment. Therefore, the total return compared to the cost of growing and handling will determine the profitableness of growing corn for each individual farmer.

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[1] U. S. Crops Reporting Board Year 1937 (Preliminary).

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Corn Varieties

There are two large groups of corn varieties, one comprising the older, open-pollinated varieties, and the other including the more recently developed hybrid varieties. These two groups differ not only in the manner by which they were developed but also in the methods to be followed in producing stock seed from year to year. Most open-pollinated varieties were developed by practical corn breeders who selected the seed from what they considered to be the best plants from year to year. During the early period of varietal improvement, a considerable amount of natural crossing took place between different varietal types. Later on, the breeders began to make careful selection for uniform and productive lines, and gradually developed a large number of varieties with fairly well-defined identifying characteristics. Many of these varieties were outstanding in performance, and many of them are still being grown.

It should be pointed out, however, that varietal strains abound which may have lost some of the identifying characteristics of the original strain from which they were selected. The relative ease by which the characteristics of an open-pollinated variety may be changed by different growers consistently selecting for different strain types has resulted in the isolation of innumerable strains within all important varieties. Some of these strains may be true to type as well as productive; others may be neither. For example, as shown in Table 2, seven different strains of the variety Minnesota 13 were grown at the college in a yield trial. There was a difference of two weeks in the time of maturity between the earliest and the latest strains and a difference of 34 bushels per acre in yield between the poorest and the best strains. Growers who want to grow a particular open-pollinated variety should bear these considerations in mind when buying new seed. Unless a reliable, economical seed source is available for the particular strain they wish to grow, the home selection of seed is strongly recommended.

TABLE 2.--PERFORMANCE OF SEVEN DIFFERENT STRAINS OF MINNESOTA 13 AT AMHERST IN 1937

Strain	Maturity Dates	Yields per Acre	
		Grain Bu.	Stover Lb.
A	8/26	34	1900
B	8/29	43	2550
C	8/30	47	3140
D	9/7	58	3790
E	9/8	69	4980
F	9/9	68	5750
G	9/9	66	5280

Hybrid corn varieties were developed by men with a scientific background who applied the principles of genetics to the problem of improving corn varieties. In a fairly short time, these men have produced varieties of corn which, under satisfactory growing conditions, surpass open-pollinated strains in productiveness, uniformity, resistance to disease, resistance to drought, ability to withstand wind, and other important characteristics. New and continually better hybrids are being introduced, and it is probable that most of those which are now offered for sale will soon be replaced by still better ones. In the light of present knowledge of genetics, the improved corn varieties of the future will be hybrids.

The term "hybrid" does not refer to a cross between different varieties of corn, but to a cross between inbred lines or combinations of such lines. A large number

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of inbred lines, the building units for all hybrids, have been developed from open-pollinated varieties by successive years of inbreeding operations within the different varieties.

An excellent discussion of how inbred lines are produced and how hybrid crosses are made will be found in the references cited below:

The What and How of Hybrid Corn. U. S. D. A. Farmers' Bulletin No. 1744. 1935.

Hybrid Corn and Its Place in Michigan. Michigan State College Extension Bulletin 195. 1939.

The production of hybrid seed corn is an expensive operation because it requires rather extensive facilities for carrying along foundation material and also because it requires careful and expert manipulation of the stock material to insure the reliability of the hybrid seed. As might be expected, good hybrid seed corn is necessarily more expensive than good seed of open-pollinated varieties, but the extra cost is an insignificant item when the superior performance of well-adapted hybrid varieties is taken into consideration. This is assuming, of course, that conditions of soil fertility and soil moisture and other external factors are favorable for normal plant growth. Whenever one or more factors such as soil fertility or soil moisture limit the productivity of the corn plant, the increased yields of hybrid varieties over open-pollinated varieties are likely to be small and their use may not be economically justified. It must be strongly emphasized concerning hybrid corn varieties that **the succeeding year's supply of seed cannot be selected from a field planted to a hybrid variety. A new supply of seed must be obtained each year.** Any attempt to select one's own seed will only lead to disappointing results.

Selecting a Corn Variety

The selection of a corn variety depends upon the purpose for which corn is being grown, whether for grain or silage, upon the local soil and climatic conditions, and upon the personal preference of the grower. There are certain guiding principles, however, which the Massachusetts grower can follow when choosing a variety.

In general, the later a variety matures, the greater will be its yield of stover and to some extent its yield of grain. This is assuming that maturity is reached before a killing frost. There are many other seasonal and cultural factors which will affect the yields and the maturity of all varieties. Hot summers with adequate rainfall will produce good yields and early maturity. Periods of drought

TABLE 3.--VARIATION IN TIME OF MATURITY FOR EIGHT CORN VARIETIES GROWN AT AMHERST, 1935-1938

Variety	Maturity Date			
	1935	1936	1937	1938
Davis Flint	8/24	9/8	9/1	—
Cornell 11	8/27	9/19	9/1	9/2
Min-hybrid 401	8/29	9/17	9/6	9/2
Wisconsin 350	8/27	9/20	—	9/6
Cornell 29-3	—	9/23	9/5	9/6
West Branch Sweepstakes	9/8	—	9/12	9/12
Ohio W17	—	9/27	9/17	9/15
New Jersey No. 2	—	10/5	9/23	9/15

Note: Varieties were planted on May 19-21 each year.

at critical growth stages will hasten maturity but reduce yields. Cold, wet seasons will retard growth, delay maturity, reduce yields, and greatly increase the danger of fall frost injury.

In selecting a variety for grain in some sections, therefore, a relatively early maturing variety must be chosen which, though not producing maximum yields of either grain or stover in favorable corn seasons, can be relied upon to produce good yields of grain and fair yields of stover during unfavorable corn seasons. Later maturing varieties will give much higher yields of both grain and silage in favorable growing seasons, but in an unfavorable growing season can be used only for silage or as forage.

Determination of the relative length of growing season required at Amherst for different varieties is important because the Amherst season may vary appreciably from the length of growing season in the regions where those varieties originated. For example, varieties which mature in 110 days in some sections of the Corn Belt may require 120 to 130 days at Amherst. The relative maturity dates for the various hybrid and open-pollinated varieties is the most important information that is contained in the table summaries.

Seasonal, cultural, and local soil conditions are so variable that differences in yields must be wide before they are significant. Consequently, the varieties have been grouped according to their respective maturity dates rather than their respective yields.

A good rule to follow in selecting a new corn variety which will be adapted to local conditions is to choose one whose maturity date is similar to that of a familiar, well-adapted variety. For example, if an early hybrid variety is desired at Amherst, choose one which matures about the same time as Cornell 11; for a medium late hybrid, choose one whose maturity date is similar to that of Westbranch Sweepstakes; and for a late hybrid, select one similar to Lancaster Sure Crop. Other parts of the State will have to use different varieties as comparable standards, but the same principle of comparing the maturity dates of new varieties with those of old ones to determine adapted strains will apply in all areas.

Defining Corn Areas

Height above sea level and nearness to the ocean are the main factors determining the relative degree of summer heat and length of growing period. Because of wide variation of altitudes within the State, marked differences occur in length of growing season. Weather records indicate that at higher elevations the season is at least a month shorter and average summer temperatures are several degrees lower. Coastal sections are of low altitude and are further modified by tempering winds which in general tend to lengthen the period between killing frosts but also tend to lower the summer temperature to a point less effective for early and midseason growth of corn.

The corn types likely to mature in any area may be determined largely on the basis of elevation. The accompanying general elevation map of Massachusetts indicates the major difference in altitudes and may serve roughly to define areas as to relative suitability for maturing varieties.

Other factors within an area are important, however. Frost pockets may shorten the growth period considerably in local areas or fields (usually low areas). Also cold wet soils may delay planting beyond the normal period. Such local conditions affect materially the selection of corn that can mature.

Three general areas are roughly defined as to suitability for maturing corn for husking.

Area I — Elevations up to 500 feet

Maturing Medium Early Dents and Late Flints. This includes the Connecticut Valley, part of Essex County, southwestern sections of Plymouth, Bristol, Norfolk counties, valley sections of southeastern Worcester County, and possibly the Cape. Those sections bordering Rhode Island are probably most favored. The varieties included in this group will produce good yields of both grain and stover.

Area II — Elevations from 500 to 800 feet

Maturing Early Dents and Medium Early Flints. This includes the remaining lower areas east of Worcester, except for local frost pockets, one of which may center around Mansfield. Included also are the intermediate elevations between Worcester and the Connecticut Valley, those intermediate elevations bordering west of the Connecticut Valley, and the valley sections of Berkshire County. (Williamstown and Sheffield are probably most favored.) Varieties adapted to these sections will consistently produce good yields of grain but only fair yields of stover.

Area III — Elevations from 800 to 1,500 feet

Maturing Early Flints and Very Early Dents. This includes the higher plateau regions of Worcester and the western counties with the exception of the two higher mountain range lands of the Berkshire Hills. Only fair yields of grain can be expected from varieties which will mature in these areas. Stover yields will always be low.

Growing Corn for Grain and Silage

The Dent varieties more commonly grown for grain over much of the Corn Belt as well as in the states like Pennsylvania and New Jersey are included in the group of "Late Grain and Silage Varieties." In favorable seasons, the better yielding strains will produce excellent yields of both grain and stover in Area I. In unfavorable seasons, they can be used only for silage and green or dry forage.

When these varieties are used for silage, the same distinction as to areas may apply, except that the relatively larger, later maturing varieties may be grown to produce more tonnage since maturity beyond the hard roasting ear stage is not required. To grow varieties too late for proper ear development, however, means handling excess water and results in somewhat inferior ensilage. Late maturing varieties from the Southern States fall into this group. They will produce large quantities of stover but little if any grain. If varieties are grown for silage which mature earlier than necessary, maximum silage yields will be needlessly sacrificed.

Fitting the Corn Land

Selecting Corn Land. Corn grows well on sod land after plowing. Cultivation while growing the crop facilitates the rotting of the sod in preparation for later reseeding. Corn is often continued on the same land two or more years if the area suitable for corn is limited by reason of poor drainage or excessive stoniness of other land on the farm. If a cash crop like potatoes is also grown, it usually does better following corn rather than sod, partly because grubs and wire worms are usually worse the first season after sod and may cause serious injury to the cash crop. Heavy and poorly drained soils are least satisfactory for corn in most seasons.

Manuring the Corn Land. Liberal use of manure on corn land is suggested. The corn benefits, and the greatest value from manure and its organic matter is obtained when it is applied *in* the soil. It makes little difference to the crop whether manure is disked or plowed under, the decision being largely a matter of convenience and ease of handling. For this reason, plowing under is quite common, especially when using strawy manure, to facilitate later seed bed preparation and possibly to reduce weed infestation from the manure.

Fertilizing with Manure, Phosphorus in the Row. Rather liberal use of manure, 16 tons or more, to which superphosphate may have been added in the stable, provides excellent fertility *to grow* the corn. A *row* application of 100 to 300 pounds of superphosphate or of a mixed fertilizer high in phosphorus is also valuable *to start* the crop. Young seedlings seem to require phosphorus and plenty of it near the seed to start a good root system. Rows so treated on the college farm grew faster and matured grain a week earlier than rows on the manure alone. Starters other than superphosphate often used include: ammo-phos 11-48-0, or mixtures such as 4-12-4, 4-16-4, or 4-16-8, in these or higher grades.

A 12-ton yield of silage corn removes almost 90 pounds each of nitrogen and potash — approximately all that is contained in 8 to 10 tons of stable manure. Because there is a considerable drain of soil nutrients in growing corn and because manure is commonly estimated to yield only about half its fertility for crop use the first season, farmers use manure liberally. In many cases, applications of 16 tons or more of manure are made on land for corn. The fertility remaining after the removal of the corn thus benefits succeeding crops.

Fertilizing without Manure. Corn occasionally is grown without manure. Adequate amounts of commercial fertilizer ordinarily produce good yields. Calculated simply on the basis of nutrients removed in cropping, again, the 12-ton yield of corn removes twice the amount of nitrogen and all the potash that would be furnished in 1,000 pounds per acre of 4-8-8. The cost of this fertilizer treatment will not greatly exceed the probable value and labor cost of the ordinary manure and superphosphate practice. And since sweet corn growers commonly apply 1,000 to 1,500 pounds or more of similar fertilizer to effect early maturity, important also in forage corn production, a 1,000-pound rate can hardly be termed excessive for the bigger silage corns which produce the greater tonnage. Adequate supply of phosphorus and potash tends to promote sturdy plants and good ear development.

The amount of fertilizer to apply depends on the residual soil fertility from previous crop practice, the variety and size of corn to be grown, and the owner's desire to maintain fertility. The use of 4-8-8, 4-12-4, or 5-10-5 grades of fertilizer, 600 to 1,000 pounds to the acre, is suggested. The same amount of plant food is obtained from 300 to 500 pounds of the higher analysis grades, such as 8-16-16, 8-24-8, or 8-16-8, and it is often slightly cheaper and more convenient to apply grades of this analysis.

Directions for the home mixing of fertilizers are sometimes requested. The following mixtures contain the same amount of plant foods as is contained in 1,000 pounds of a complete fertilizer of the indicated analysis. They should be applied about the same day they are mixed; otherwise lumping will occur.

1.

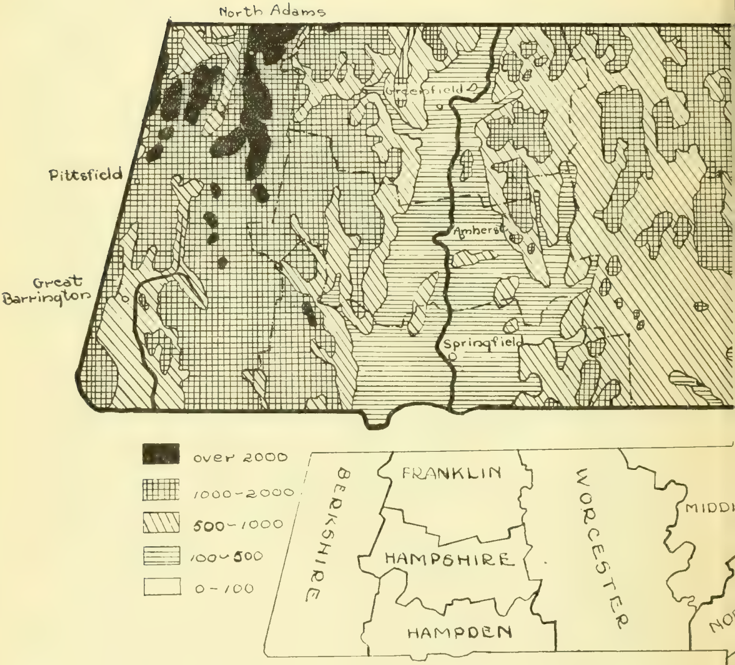
200 lb. Sulfate of Ammonia
400 lb. Superphosphate (20%)
160 lb. Muriate of Potash

760 lb. mixture= 1,000 lb. of 4-8-8
76 lb. mixture= 100 lb. of 4-8-8

2.

100 lb. Sulfate of Ammonia
170 lb. Ammo-Phos (11-48-0)
160 lb. Muriate of Potash

430 lb.= 1,000 lb. of 4-8-8
43 lb.= 100 lb. of 4-8-8


North Adams
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Greenfield
Amherst
Springfield
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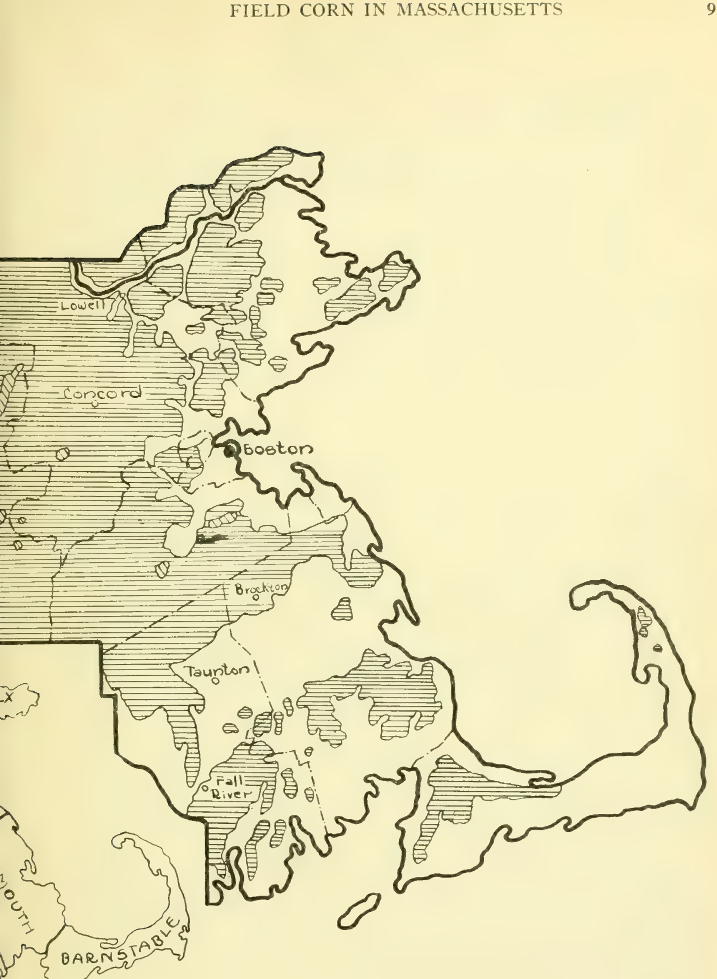
Lowell
Concord
Boston
Brockton
Taunton
Fall River
X
OUTH
BARNSTABLE

Massachusetts

3.

200 lb. Sulfate of Ammonia
600 lb. Superphosphate
80 lb. Muriate of Potash

880 lb. mixture = 1,000 lb. of 4-12-4
88 lb. mixture = 100 lb. of 4-12-4

4.

200 lb. Sulfate of Ammonia
800 lb. Superphosphate
80 lb. Muriate of Potash

1,080 lb. mixture = 1,000 lb. of 4-16-4
108 lb. mixture = 100 lb. of 4-16-4

5.

200 lb. Sulfate of Ammonia
800 lb. Superphosphate
160 lb. Muriate of Potash

1,160 lb. mixture = 1,000 lb. of 4-16-8
116 lb. mixture = 100 lb. of 4-16-8

Applying Fertilizers. Fertilizer is definitely more effective when drilled each side of the row but not in contact with the seed than when applied broadcast. If a modern planter is used with *proper* drill attachment to place the fertilizer in separate bands almost an inch away from the seed, then most or all the fertilizer may be drilled. With check row planters, amounts of fertilizer above 500 pounds should be drilled in continuous bands rather than dropped only at the hills.

Caution is necessary in the use of mixed fertilizer for row applications. Even relatively small amounts applied directly above or below the seed tend to be unsafe, and, if applied in contact with the seed, will probably burn. Old type distributors which tend to place fertilizer materials quite close to the seed are unsafe except for the application of superphosphate or for part of the usual corn grade fertilizers. The remainder of the fertilizer can be broadcast either before planting or as side dressing at the time of first cultivation when the corn is up.

Another method of applying considerable fertilizer safely yet efficiently is suggested when planting by hand or with old type planters. The nitrogen and potash materials, 200 and 150 pounds per acre, respectively, may be applied first, either broadcast and harrowed in when fitting the seed bed, or topdressed after the field is planted. Row application of the superphosphate, 300 to 500 pounds, may then be made safely in the planter or by hand.

Liming Corn Land. Since seeding of grass and clovers commonly follows corn, attention should be given to applying extra superphosphate broadcast and lime if needed. This should be included when preparing in the spring, if the clover is to be seeded in the last cultivation of corn. On strongly acid soils, lime will benefit both the corn and the clover. And the extra superphosphate broadcast, about 500 pounds, is also valuable for the clover.

Unless soils are strongly acid (below pH 5.5) corn may do well without lime, especially if considerable manure is used. In such cases, and where plowing after corn is to be practiced before seeding to clovers, lime could be applied on the furrow just before the clover. However, on very acid soils, or in case alfalfa is to follow corn, 1½ to 2 tons of lime could be applied to advantage when fitting the land for corn. Later, when this land is again plowed following the corn, further lime may be applied.

Fitting the Seed Bed for Corn. Thorough harrowing before planting facilitates weed control later. Harrow deep to pulverize the clods beneath. A smoothing harrow and plank drag will smooth the surface ready for planting.

Planting

Early planting is of great importance, as this crop requires every day of growing weather between frosts for maximum production. But it is of no use to plant before the soil is warmed up and the seed bed is well prepared. A good rule is to plant corn while apple trees are in bloom or when oak leaves are the size of squirrel's ears. Check row planting on level land where soil erosion is not serious allows cultivation both ways and is an advantage in controlling weeds. Dipping the seed in tar or some effective crow repellent is important to prevent crows and other birds from scratching out newly planted seed.

The amount of seed necessary to plant an acre will vary with the variety and to some extent with the purpose for which it is being grown. Low-growing, early-maturing varieties should be planted relatively thickly in rows which are comparatively close together to produce maximum yields; while for tall-growing, late-maturing varieties the converse is true. Seeding rates are often heavier when corn is grown for silage than when it is grown for grain. The distance between rows will vary from 36 to 42 inches. The size of kernel, which varies from one variety to another and between different grades of the same variety, will also influence the seeding rate.

The seeding rate, therefore, will vary from 8 to 15 pounds to the acre, depending upon the variety grown, the distance between rows, and the grade of seed planted. The best yield of sound ears will probably result when there are three and occasionally four stalks to the hill with check-planted corn, and one stalk every nine to twelve inches of drilled row.

The same rate holds true for best silage if full ear development is desired. Thicker planting, however, on fertile soil of adequate moisture will result in somewhat greater yield of dry matter and total digestible nutrients, but fewer ears and lower feeding value per ton. For this reason, planting at a six-inch spacing or less is seldom recommended except for greatest bulk yields or for green fodder where finer stems are desirable.

Cultivating

If the seed bed has been well prepared, later cultivation costs may be lessened. The last harrowing should immediately precede planting in order that no weeds may get a flying start. Another harrowing with the smoothing harrow or weeder just before the corn comes up, and again repeated lengthwise of the rows after the corn is three or four inches high, will probably save two trips with the cultivator and several men with hoes.

There is no advantage in deep cultivation at all, except as a final resort to tear up a rank growth of weeds. And it is very important that all later cultivations be *shallow* to avoid real damage to the vast system of fine feeding roots of the corn.

Harvesting

Silage corn should be cut before a killing frost, when the grain is at the hard dough or glazing stage and the leaves are mostly green. Stage of maturity at harvest is one of the principal factors which determine the amount and quality of nutrients obtained from an acre of corn, as is well illustrated in the following data from the North Dakota Experiment Station.

TABLE 4--COMPOSITION OF AN ACRE OF CORN AT DIFFERENT STAGES OF MATURITY (POUNDS PER ACRE)

Stage of Maturity	Green Weight	Dry Weight	Protein	Fat	Nitrogen-free Extract
Tassel	26,702	4,307	388	47	2,288
Milk	29,636	6,000	461	73	3,283
Dough	25,209	6,669	501	142	4,002
Glazed	21,138	6,910	533	161	4,213
Ripe	16,106	6,612	495	145	4,030

It should be noted that while this acre of corn reached its maximum green weight in the milk stage, it gained approximately half a ton extra dry matter, largely digestible, when advanced to the hard dough stage perhaps two weeks later. If left until the full glazed stage, however, much of the grain will be so hard that some kernels may pass through animals undigested.

Corn for husking should preferably attain the ripe state, with leaves drying up, before killing frosts to avoid undue spoilage which might follow either in the stook or when the ears are finally cribbed.

Controlling The Corn Borer

The European corn borer is the most serious pest affecting the plant. The greenish white worm, about 1/2 to 2/3 of an inch long with brown head, develops from eggs laid by moths. The worms tunnel in the stalks and tend to winter over in the above-ground portions of corn stubble, stalks, or weeds left on the surface of the ground. In the spring, they emerge as moths to renew the infestation. They are destroyed by ensiling corn, shredding or feeding it to livestock, or by burning and by plowing under completely all trash and stubble in the fall. Present regulations demand that all corn stubble be plowed under by December 1, and stalks be destroyed by April 10.

No borers are located in the underground portions of the plants. Therefore, if all corn stalks are cut at or below the ground level so that no stubble remains and if no waste stalks are left on the field, the plowing of such fields is not demanded.

Using a special attachment on the binder for ground cutting, or using a hand mattock or ordinary hoe with the handle shortened and bent slightly sidewise to the blade, are common methods used in cutting corn to leave no stubble above the ground.

Only where stubble is thus removed and no trash is left can seeding down in the last cultivation of corn be practiced without necessity for plowing the land, according to the present requirements by law.

Reducing Soil Erosion

To reduce loss of soil by erosion, plant across rather than up and down the slope. The rows soon established serve as dams to check runoff. The more nearly level the rows are, following the contour of the slope, the more effective is this measure of control.

Likewise, to reduce runoff from plowing of the stubble, work the land across the slope and if possible seed immediately a catch crop of rye, wheat, or barley, 2½ to 3 bushels to the acre, as an effective measure to retard erosion.

TABLE 5.--COMPARISON OF CORN VARIETIES AT AMHERST, 1936

(The listing of sources of seed used in these trials is justified only for purposes of identification and should not be interpreted as an intention of endorsement. Nevertheless the authors desire to express their appreciation for the cooperation of the several commercial seed companies, private seedsmen, and experiment stations which supplied seed samples.)

Variety	Seed Source	Maturity Dates	Yields per Acre	
			Grain Bu.	Stover Lb.
Early Dent and Medium Early Flint				
*Sheffield Flint	K. C. Livermore, N. Y.	9/7	37	2,950
*Yates Flint	K. C. Livermore	9/8	58	3,300
*Davis Flint	Perley Davis, Mass.	9/8	41	2,800
Min-hybrid 402	Minnesota Agr. Exp. Sta.	9/13	50	2,850
Medium Early Dent and Late Flint				
Min-hybrid 401	Minnesota Agr. Exp. Sta.	9/17	60	2,850
Wisconsin 455	Wisconsin Agr. Exp. Sta.	9/19	67	3,800
*Cornell 11	Eastern States Farmers' Exchange	9/19	57	2,500
Wisconsin 350	Wisconsin Agr. Exp. Sta.	9/20	63	3,040
Wisconsin 406	Wisconsin Agr. Exp. Sta.	9/21	67	3,600
Wisconsin 525	Wisconsin Agr. Exp. Sta.	9/21	61	4,010
*Rustler's White	Massachusetts Agr. Exp. Sta.	9/21	54	3,900
Wisconsin 450	Wisconsin Agr. Exp. Sta.	9/23	62	4,500
Cornell 29-3	Eastern States Farmers' Exchange	9/23	72	5,600
*Williams' Yellow Dent	M. H. Williams, Mass.	9/24	61	4,560
Late Grain and Silage				
Ohio W17	Ohio Agr. Exp. Sta.	9/27	67	7,900
Iowealth 10	Michael-Leonard Seed Co., Iowa	9/28	62	4,400
*Somerset Leaming	New Jersey Agr. Exp. Sta.	9/29	72	7,200
*Lancaster Sure Crop	New Jersey Agr. Exp. Sta.	10/1	64	9,200
*Mercer White Cap	New Jersey Agr. Exp. Sta.	10/2	67	8,000
*Reid's Yellow Dent	New Jersey Agr. Exp. Sta.	10/3	72	9,000
*North Central Iowealth	Michael-Leonard Seed Co.	10/3	64	8,200
New Jersey Hybrid No. 2	New Jersey Agr. Exp. Sta.	10/5	69	9,170
*Reid's Yellow Dent	Illinois Agr. Exp. Sta.	10/5	66	11,750
*Krug	Illinois Agr. Exp. Sta.	10/5	66	8,850
Iowa 13	Iowa Agr. Exp. Sta.	10/5	66	8,940
Iowealth 26	Michael-Leonard Seed Co.	10/5	68	10,830
Iowealth 27	Michael-Leonard Seed Co.	10/6	73	11,560
Iowealth 30	Michael-Leonard Seed Co.	10/6	66	13,130
*Shenandoah	T. W. Wood & Sons, Va.	10/6	62	12,030
*West Branch Sweepstakes	T. W. Wood & Sons	10/6	35	6,000
*Hulsart's Yellow Dent	New Jersey Agr. Exp. Sta.	10/6	63	10,830
Funk's 220	Funk Bros. Seed Co., Ill.	10/8	63	9,540
Late Silage				
*Pamunkey	T. W. Wood & Sons	—	27	16,740
*Virginia Eureka	T. W. Wood & Sons	—	25	19,140
*Hastings' Prolific	T. W. Wood & Sons	—	—	22,000
*Tuxpan	T. W. Wood & Sons	—	—	24,000

TABLE 6.--COMPARISON OF CORN VARIETIES AT AMHERST, 1937

Variety	Seed Source	Maturity Dates	Yields per Acre	
			Grain Bu.	Stover Lb.
Very Early Dent and Early Flint				
*North Dakota Exp.Sta.Flint	O. H. Will Co., N. D.	8/22	31	1,420
*Assiniboine Flint	O. H. Will Co.	8/23	19	1,060
*Gehu Flint	Northrup King, Minn.	8/23	26	1,240
*Northwestern Dent	Northrup King	8/23	33	1,420
*Falconer Flint	O. H. Will Co.	8/24	29	2,900
*Minnesota 13 Dent	Eastern States Farmers' Exchange	8/26	34	1,900
*Minnesota13Dent(Haney's)	Farmers' Seed Nursery Co., Minn.	8/29	43	2,550
*Sheffield Flint	K. C. Livermore, N. Y.	8/29	42	4,860

The asterisk (*) indicates open-pollinated varieties.

TABLE 6--CORN VARIETIES, 1937—Continued.

Variety	Seed Source	Maturity Dates	Yields per Acre	
			Grain Bu.	Stover Lb.
Early Dent and Medium Early Flint				
*Minnesota 13 (Boyd's)	O. H. Will Co.	8/30	47	3,140
*Mercer Flint	Northrup King	8/31	56	2,960
Min-hybrid 402	Minnesota Agr. Exp. Sta.	8/31	48	2,600
Wisconsin 404	Wisconsin Agr. Exp. Sta.	8/31	49	3,910
*Yates Flint	K. C. Livermore	9/1	49	4,350
*Davis Flint	Perley Davis, Mass.	9/1	56	4,680
Wisconsin 25	Northrup King	9/1	35	1,960
*Cornell 11, Lot 1	Eastern States Farmers' Exchange	9/1	66	4,800
*Cornell 11, Lot 2	Eastern States Farmers' Exchange	9/1	57	3,500
Medium Early Dent and Late Flint				
Cornell 29-3	Eastern States Farmers' Exchange	9/5	71	5,040
Wisconsin 455	Wisconsin Agr. Exp. Sta.	9/6	59	4,150
Wisconsin 525	Wisconsin Agr. Exp. Sta.	9/6	59	4,980
Min-hybrid 401	Minnesota Agr. Exp. Sta.	9/6	59	3,320
*Minnesota 13	Northrup King	9/7	58	3,790
*Golden Nugget Flint	Eastern States Farmers' Exchange	9/7	44	4,090
*Early Huron	F. H. Woodruff & Sons, Conn.	9/7	51	3,790
Wisconsin 456	Wisconsin Agr. Exp. Sta..	9/8	62	5,450
*Minnesota 13	W. H. Jacques, Wis.	9/8	69	4,980
Canada Leaming	Connecticut Agr. Exp. Sta.	9/8	55	8,000
*Minnesota 13 (Large Type)	Farmers' Seed Nursery Co.	9/9	68	5,750
*Minnesota13(CentralType)	Farmers' Seed Nursery Co.	9/9	66	5,280
*Early Murdock	Farmers' Seed Nursery Co.	9/9	73	4,860
*Davis Early Huron	Joseph Harris, N. Y.	9/9	64	4,740
*Rustler's White	Massachusetts Agr. Exp. Sta.	9/10	59	5,420
*Wisconsin 12	Northrup King	9/10	49	4,800
*Wisconsin 8	Northrup King	9/11	48	4,270
*Somerset Leaming	New Jersey Agr. Exp. Sta.	9/11	76	11,560
*Longfellow Flint	Emerson Seed Co., Mass.	9/11	44	6,310
Min-hybrid 403	Minnesota Agr. Exp. Sta.	9/12	66	3,850
Iowealth No. 2	Michael-Leonard Seed Co.	9/12	71	5,280
Min-hybrid 301	Minnesota Agr. Exp. Sta.	9/12	82	5,800
*Williams' Yellow Dent	M. H. Williams, Mass.	9/12	61	6,050
Late Grain and Silage				
*West Branch Sweepstakes	Eastern States Farmers' Exchange	9/12	71	8,710
Iowealth 1	Michael-Leonard Seed Co.	9/12	60	6,050
Funk's G7	Funk Bros. Seed Co.	9/13	88	9,300
Iowealth AP	Michael-Leonard Seed Co.	9/13	75	8,420
Wisconsin 575	Wisconsin Agr. Exp. Sta.	9/13	70	9,540
Wisconsin 682	Wisconsin Agr. Exp. Sta.	9/13	64	8,530
Cornell 29-5	Cornell Agr. Exp. Sta., N. Y.	9/14	83	8,710
Iowealth 10	Michael-Leonard Seed Co.	9/15	65	6,930
Wisconsin 673	Wisconsin Agr. Exp. Sta.	9/15	78	10,600
Funk's G57	Funk Bros. Seed Co.	9/16	96	10,800
Ohio W17	Ohio Agr. Exp. Sta.	9/17	76	10,000
Funk's G19	Funk Bros. Seed Co.	9/18	70	9,360
Funk's G55	Funk Bros. Seed Co.	9/18	69	9,190
Funk's G8	Funk Bros. Seed Co.	9/19	77	9,010
Iowealth 26	Michael-Leonard Seed Co.	9/19	65	10,190
Iowealth 27	Michael-Leonard Seed Co.	9/20	85	11,440
National 117	National Hybrid Corn Co., Iowa	9/20	77	11,380
Indiana 608	Indiana Agr. Exp. Sta.	9/21	75	8,360
Indiana 400	Indiana Agr. Exp. Sta.	9/21	69	11,080
Funk's 212	Funk Bros. Seed Co.	9/21	84	11,910
Funk's 244	Funk Bros. Seed Co.	9/21	76	11,500
*North Central Iowealth	Michael-Leonard Seed Co.	9/22	71	8,830
*Hulsart's Yellow Dent	New Jersey Agr. Exp. Sta.	9/23	78	16,360
New Jersey No. 2	New Jersey Agr. Exp. Sta.	9/23	85	16,500
Iowealth AQ	Michael-Leonard Seed Co.	9/23	80	9,590

The asterisk (*) indicates open pollinated varieties.

Variety	Seed Source	Maturity Dates	Yields per Acre	
			Grain Bu.	Stover Lb.
*Mercer White Cap	New Jersey Agr. Exp. Sta.	9/24	76	11,440
*Improved Leaming	Eastern States Farmers' Exchange	9/24	72	11,790
*Lancaster Sure Crop	New Jersey Agr. Exp. Sta.	9/24	86	11,560
*Lancaster Sure Crop	Eastern States Farmers' Exchange	9/24	75	13,200
Funk's 220L	Funk Bros. Seed Co.	9/25	88	10,670
*Krug	Eastern States Farmers' Exchange	9/25	65	8,530
Indiana 671C	Indiana Agr. Exp. Sta.	9/25	67	11,600
Indiana 810	Indiana Agr. Exp. Sta.	9/25	66	11,200
Iowealth No. 20	Michael-Leonard Seed Co.	9/25	60	10,550
*Long's Champion	Eastern States Farmers' Exchange	9/25	60	10,800
Funk's G92	Funk Bros. Seed Co.	9/26	83	11,560
*Reid's Yellow Dent	New Jersey Agr. Exp. Sta.	9/26	61	16,100
*Pride of the North	F. H. Woodruff & Sons	9/26	64	13,200
Late Silage				
*Pamunkey	T. W. Wood & Sons, Va.	—	20	18,210
*Tuxpan	T. W. Wood & Sons	—	—	18,500

TABLE 7.--COMPARISON OF CORN VARIETIES AT AMHERST, 1938[1]

Variety	Seed Source	Maturity Dates
Early Dent and Medium Early Flint		
Min-hybrid 402	Minnesota Agr. Exp. Sta.	8/31
Min-hybrid 401	Minnesota Agr. Exp. Sta.	9/2
*Cornell 11	Cornell Agr. Exp. Sta., N. Y.	9/2
Wisconsin 404	Wisconsin Agr. Exp. Sta.	9/3
Wisconsin 355	Wisconsin Agr. Exp. Sta.	9/3
Medium Early Dent and Late Flint		
Wisconsin 456	Wisconsin Agr. Exp. Sta.	9/5
Min-hybrid 301	Minnesota Agr. Exp. Sta.	9/6
Wisconsin 350	Wisconsin Agr. Exp. Sta.	9/6
Cornell 29-3	Cornell Agr. Exp. Sta.	9/6
Wisconsin 531	Wisconsin Agr. Exp. Sta.	9/7
Canada Leaming	Eastern States Farmers' Exchange	9/7
Michigan 1218	Michigan Agr. Exp. Sta.	9/8
Funk's G337	Funk Bros. Seed Co.	9/8
National 110	National Hybrid Corn Co., Iowa	9/8
Iowealth 2	Michael-Leonard Seed Co.	9/9
Iowealth AP	Michael-Leonard Seed Co.	9/9
Pioneer Hi-Bred 355	Pioneer Hi-Bred Corn Co., Iowa	9/10
Ohio K23	Ohio Agr. Exp. Sta.	9/10
Pioneer Hi-Bred 357	Pioneer Hi-Bred Corn Co.	9/11
Late Grain and Silage		
*West Branch Sweepstakes	Eastern States Farmers' Exchange	9/12
Cornell 29-5	Cornell Agr. Exp. Sta.	9/12
*Canada Krug (Flint x Dent)	Eastern States Farmers' Exchange	9/12
DeKalb 202	DeKalb Agr. Ass'n. Inc., Ill.	9/13
National 112	National Hybrid Corn Co.	9/13
DeKalb 404-A	DeKalb Agr. Ass'n. Inc.	9/14
Iowa 931	Iowa Agr. Exp. Sta.	9/14
DeKalb 204	DeKalb Agr. Ass'n. Inc.	9/14
DeKalb 493-4	DeKalb Agr. Ass'n. Inc.	9/14
DeKalb 404-4	DeKalb Agr. Ass'n. Inc.	9/14
Iowealth 15	Michael-Leonard Seed Co.	9/14
Iowealth 20B	Michael-Leonard Seed Co.	9/14

The asterisk (*) indicates open-pollinated varieties.

(1) No yields were obtained on account of storm damage.

TABLE 7--CORN VARIETIES, 1938—Continued.

Variety	Seed Source	Maturity Dates
Illinois 570	Illinois Agr. Exp. Sta.	9/14
Illinois 751	Illinois Agr. Exp. Sta.	9/14
Illinois 546	Illinois Agr. Exp. Sta.	9/14
DeKalb 870	DeKalb Agr. Ass'n. Inc.	9/14
Michigan 561	Michigan Agr. Exp. Sta.	9/14
Wisconsin 644	Wisconsin Agr. Exp. Sta.	9/14
Wisconsin 645	Wisconsin Agr. Exp. Sta.	9/14
Wisconsin 606	Wisconsin Agr. Exp. Sta.	9/14
Wisconsin 625	Wisconsin Agr. Exp. Sta.	9/14
DeKalb 421	DeKalb Agr. Ass'n. Inc.	9/14
Illinois 498	Illinois Agr. Exp. Sta.	9/14
Illinois 499	Illinois Agr. Exp. Sta.	9/14
Funk's G-315	Funk Bros. Seed Co.	9/14
Funk's G-7	Funk Bros. Seed Co.	9/15
Funk's G-14	Funk Bros. Seed Co.	9/15
Indiana 417	Indiana Agr. Exp. Sta.	9/15
Pioneer Hi-Bred 323	Pioneer Hi-Bred Corn Co.	9/15
Ohio K35	Ohio Agr. Exp. Sta.	9/15
Wisconsin 696	Wisconsin Agr. Exp. Sta.	9/15
Wisconsin 680	Wisconsin Agr. Exp. Sta.	9/15
Ohio W17	Ohio Agr. Exp. Sta.	9/15
Iowa 939	Iowa Agr. Exp. Sta.	9/15
Pioneer Hi-Bred 315	Pioneer Hi-Bred Corn Co.	9/15
Pioneer Hi-Bred 322	Pioneer Hi-Bred Corn Co.	9/15
*Lancaster Sure Crop	New Jersey Agr. Exp. Sta.	9/15
Iowa 942	Iowa Agr. Exp. Sta.	9/15
Iowealth AF	Michael-Leonard Seed Co.	9/15
Iowealth BC4	Michael-Leonard Seed Co.	9/15
Iowealth CJ	Michael-Leonard Seed Co.	9/15
Iowealth 16	Michael-Leonard Seed Co.	9/15
Funk's 212	Funk Bros. Seed Co.	9/15
Iowealth AQ	Michael-Leonard Seed Co.	9/15
National 114	National Hybrid Corn Co.	9/15
New Jersey 2	New Jersey Agr. Exp. Sta.	9/15
Indiana 608B	Indiana Agr. Exp. Sta.	9/15
Indiana 614	Indiana Agr. Exp. Sta.	9/15
Indiana 800B	Indiana Agr. Exp. Sta.	9/15
U. S. 44	Ohio Agr. Exp. Sta.	9/15
New Jersey 4	New Jersey Agr. Exp. Sta.	9/15
U. S. 13	Ohio Agr. Exp. Sta.	9/15
Iowealth 27	Michael-Leonard Seed Co.	9/15
DeKalb 629	DeKalb Agr. Ass'n. Inc.	9/15
Funk's G-8	Funk Bros. Seed Co.	9/15
Funk's 220-L	Funk Bros. Seed Co.	9/15
DeKalb 481	DeKalb Agr. Ass'n. Inc.	9/16
Iowealth AD	Michael-Leonard Seed Co.	9/16
Iowealth 52	Michael-Leonard Seed Co.	9/16
Iowealth 50	Michael-Leonard Seed Co.	9/16
National 117	National Hybrid Corn Co.	9/16
Iowealth 53	Michael-Leonard Seed Co.	9/16
Indiana 416	Indiana Agr. Exp. Sta.	9/16
Indiana 420	Indiana Agr. Exp. Sta...	9/16
Indiana 845B	Indiana Agr. Exp. Sta.	9/16
U. S. 52	Ohio Agr. Exp. Sta.	9/16
National 125	National Hybrid Corn Co.	9/16
Indiana 400	Indiana Agr. Exp. Sta.	9/16
Illinois 960	Illinois Agr. Exp. Sta.	—
Iowa 13	Iowa Agr. Exp. Sta.	—

The asterisk (*) indicates open-pollinated varieties.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

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The Effect of Feeding a Vitamin A Supplement to Dairy Cattle

By J. G. Archibald and C. H. Parsons

The role of vitamins in the diet of man and animals has become a matter of vital and practical interest. This bulletin reports the results of a two-year study of the effect of vitamin A used as a supplement to natural dairy rations.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE EFFECT OF FEEDING A VITAMIN A SUPPLEMENT TO DAIRY CATTLE

J. G. Archibald, Research Professor, and
C. H. Parsons, Assistant Professor of Animal Husbandry

Introduction

Developments within the past few years in knowledge of the numerous vitamins and their relationship to health and disease have brought about a gradual change in viewpoint regarding the adequacy in this respect of rations fed to cattle. Formerly it was quite generally held that although certain of the vitamins are doubtless essential in the ration, cattle would obtain sufficient of them from their ordinary feeds, more especially from roughage.

It is now realized that such a fortunate state of affairs does not always exist, particularly with respect to vitamin A. It has been shown that the carotene (vitamin A) content of our ordinary roughages is subject to great variation depending upon how the roughage is cured and stored, and that it may be greatly reduced or even completely destroyed by careless handling of hays and other coarse feeds.

Because of the difficulty in ordinary farm practice of obtaining at all times roughages which contain a liberal amount of carotene, there has been proposed an alternative method of insuring a sufficiency of vitamin A by adding it in concentrated form to grain mixtures. Especial interest in this practice became current about four or five years ago. Some commercial concerns began to include a vitamin A supplement in their dairy rations at some increase in cost to the consumer; others were hesitant to adopt the practice without definite evidence as to its value.

The lack of evidence based on extensive feeding trials of considerable length, led to the organization of a project at this station designed to ascertain what effect the addition of a vitamin A supplement to the grain ration would have on growth, reproduction, and milk production in the Massachusetts State College dairy herd. The results of that project, commenced in February 1935 and carried through to April 1937, form the basis of this report.

The work was done in cooperation with two commercial firms, one of which furnished the vitamin supplement (a fortified cod liver oil), while the other mixed the supplement with a special grain ration formulated at the experiment station. The grain was delivered in carload lots as needed.[1]

Method of Investigation

The entire herd of milking cows, and heifers past the calfhood stage, was used for the feeding trial, which was commenced February 1, 1935, and continued with one interruption (the pasture season of 1935, May to September inclusive) until the end of April 1937. Records are available for nineteen months of continuous feeding of the supplement (October 1, '35 to April 30, '37) and for a total of twenty-two months altogether. Approximately 150 individuals were included, 70 of which were on trial during the entire course of the experiment, either as milking cows or as heifers and later as milkers.

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[1] Acknowledgement is made to the Charles M. Cox Company, Boston, which supplied the grain mixtures with the vitamin A supplement properly blended; and to the National Oil Products Company, which furnished the standard vitamin concentrate for blending.

A double control on the efficacy of the supplement was established. Approximately one half of the heifers and one third of the milking cows were not given the supplement, and in addition the records of the older cows, for a period of several years previous to the commencement of the experiment, were available for comparison with the results secured during the trial.

The feeding and management[2] of the herd was the same as has been followed for years; viz., pasture from about May 1st to about Sept. 30th, and barn feeding from October through April, which included in addition to grain, mixed hay of average quality, liberal amounts of corn silage, and a fair allowance of mangels or beet pulp. Grain was fed at about an average ratio of 1:3, except when the cows were on pasture when it was reduced to about 1:7 or 8. The heifers did not receive any mangels or beet pulp and their grain allowance was 4 to 5 pounds per head daily. They did not receive grain while on pasture from May to October of both years. The protein level of the grain was adjusted from time to time as circumstances warranted.

TABLE 1. — AVERAGE DAILY RATIONS PER COW DURING THE BARN FEEDING SEASON OF 1935-1936 AND 1936-37, TOGETHER WITH THE AVERAGE CAROTENE CONTENT OF THE FEEDS.

	Average Pounds per Cow, Daily		Average Carotene per Pound of Feed
Hay	6.6		2,188 gamma of carotene*
Rowen	3.0		1,588 do.
Corn silage	33.8		2,063 do.
Roots	10.3		None
Beet pulp	1.7		None
Grain	11.1	With supplement	3,120** U.S.P. units of Vitamin A
		Without supplement	None

*One gamma of pure beta carotene is equal to 1.6 U. S. P. units of Vitamin A.

**By actural assay. The amount on the basis of guaranteed potency ot the supplement was 2,835 U. S. P. units per pound. Evidently a reasonable margin of safety was allowed. It is also evident that in this particular lot of grain, at least, there was a minimum of destruction of the vitamin in storage.

The vitamin A concentrate which part of the herd received was incorporated into the grain mixture at the rate of 0.25 percent (5 lbs. per ton). Except for this addition the grain mixtures were identical at any given time. The supplement used was a fortified cod liver oil. It was mixed first with wheat middlings to make what is known as a "premix," which was then blended with the rest of the feed to give the desired amount of the supplement per ton. Such a procedure is necessary wherever such small amounts of a substance are used, in order to insure its uniform distribution throughout the mixture.

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[2] Acknowledgement is made of the painstaking attention to detail, especially in the keeping of records, of the herdsmen, Thomas Muir and William Smith.

The maximum length of storage between mixing and feeding of the grain was two months. The interval was much shorter than this for the most part. During the period from February 1935 to October 1936 the supplement was guaranteed to contain 2500 U. S. P. units of vitamin A and 250 units of vitamin D per gram. From October 1936 to April 1937 the guarantee was 3000 U. S. P. units of vitamin A and 350 units of vitamin D per gram.

Translated into ordinary usage this means that a cow receiving an average amount of ten pounds of grain daily would obtain 28,350 U. S. P. units of vitamin A from the earlier lot of the concentrate and 34,020 U. S. P. units daily from the later lot. Converse and Meigs in their latest published work[3] conclude that an average of 144,000 U. S. P. units daily (the equivalent of 90,000 gamma of pure beta carotene), is necessary for normal calving. This means that most of the necessary vitamin A must have come from the feeds rather than from the supplement. As there were no indications of vitamin D deficiency in the herd, a study of the effects of the supplement in this respect was not made.

Vitamin A assays were made on the supplement, and carotene determinations were made on the various feeds used in the course of the experiment. The usual

TABLE 2. — COMPARISON OF REPRODUCTIVE FUNCTION BEFORE AND DURING THE EXPERIMENT FOR COWS IN THE HERD PREVIOUSLY AND CONTINUING IN THE HERD DURING MOST OR ALL OF THE EXPERIMENTAL PERIOD.

		All Cows		Group Receiving Vitamin A Supplement		Group not Receiving Vitamin A Supplement	
		Before Expt.	During Expt.	Before Expt.	During Expt.	Before Expt.	During Expt.
Time from calving to first heat	Days	44	49	45	49	40	51
Services required for conception	Number	2.1	1.6	2.2	1.5	1.9	1.8
Length of gestation	Days	283	281	283	281	283	280
Cases of retained placenta	Percent	8.6	20.0	9.5	22.9	6.1	13.6
Abortions	Number	2	3*	0	3*	2	0
Calves born dead	Number	2	3	2	0	0	3
Calves died some time after birth	Number	1	0	1	0	0	0
Cases of milk fever	Number	4	15	3	11	1	4

*One of these was due to *B. abortus* infection.

Other abnormalities, all occurring during the experiment, include:

One case of eversion of the uterus in the group receiving the vitamin A supplement.

Two cases of nymphomania, one in each group.

Two cases of cystic ovaries, both in the group not receiving the supplement.

One cow in the group not receiving the supplement stopped coming in heat for no apparent reason.

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[3] Converse, H. T., and Meigs, E. B. The carotene requirements for normal reproduction. (Abstract) Jour. Dairy Sci. 21 (No. 5):114. 1938.

factor (1.6) was used in converting gamma of carotene found into U. S. P. units of vitamin A as given hereafter.

Using these values together with the average daily ration fed, calculation shows that the average intake of vitamin A by individual cows in the group receiving the supplement was approximately 174,000 U. S. P. units daily, while in the group which did not receive the supplement it was approximately 142,000 U. S. P. units daily. These figures indicate that if the standard set by Converse and Meigs is correct for our conditions, the group of cows receiving the supplement had an excess of approximately 21 percent of vitamin A above requirements in their daily ration, while those not receiving the supplement were experiencing a slight deficiency of the vitamin in comparison with the standard.

A very careful record of the reproductive function of all the individuals was kept throughout the experiment. Growth of the heifers was followed by means of live weights obtained at intervals of not more than two months during each barn feeding season. The average of two weights on consecutive days, or on days with only one day intervening, was the figure used at any particular time. Complete milk records were available as a matter of routine practice in the herd. All calves dropped during the period were weighed at birth and were graded for condition by an experienced herdsman. Those saved for the herd were weighed again at one month of age. Effects on growth and reproductive function are summarized in Tables 2 to 5 inclusive.

TABLE 3. — RECORD OF THE MILKING HERD DURING THE EXPERIMENT.

		Group Receiving Vitamin A Supplement		Group not Receiving Vitamin A Supplement	
		Records during Experiment	Number of Records	Records during Experiment	Number of Records
Number of individuals			55		33
Regularity of heat		Fair+	57	Fair+	30
Interval between heats	Days	27.6	192	31.5	112
Time from calving to first heat	Days	44.9	87	51.0	41
Services required for conception	Number	1.5	98	1.7	37
Length of gestation	Days	281	57	280	14
Cases of retained placenta	Percent	16.3	80	12.8	39
Abortions	Number	3*	..	1	..
Calves born dead	Number	3	..	5	..
Calves died some time after birth	Number	4	..	0	..
Cases of milk fever	Number	11		4	

*One of these was due to *B. abortus* infection.

Other abnormalities the same as reported in the footnote to Table 2, except for one additional case of eversion of the uterus which occurred in the group receiving the Vitamin A supplement.

Discussion

From Table 2 it will be noted that in most respects the reproductive record of the herd as a whole grew worse rather than better during the course of the experiment. The average length of time from calving to first heat increased considerably and the incidence of retained placenta was much higher. The only respect in which any considerable improvement was evident was in the average number of services required for conception, which dropped from 2.1 per cow to 1.6. It is entirely possible that this improvement was due to greater virility in the bulls in service at the time.

When the data are separated into groups it seems that in some respects the group which received the vitamin A supplement lost less ground than the other group did. The period from calving to first heat was lengthened only four days while for the second group it was lengthened eleven days. There were no calves born dead in the former group while in the latter group there were three. On the other hand, there was a considerably higher incidence of retained placenta in the group receiving vitamin A supplement. Despite the much larger number of cases of milk fever in this group, the ratio "before : during" was not quite as high as in the group which did not receive the vitamin supplement.

In Table 3 some additional data have been added, records for which had not been kept prior to commencement of the experiment. Also a considerable number of young cows are included here which were not in the herd previously and con-

TABLE 4. — RECORD OF HEIFERS IN THE HERD DURING THE EXPERIMENT.

		Group Receiving Vitamin A Supplement		Group not Receiving Vitamin A Supplement	
		Records during Experiment	Number of Records	Records during Experiment	Number of Records
Number of individuals.			46		43
Average daily gain in weight............	Pounds	0.99	53	1.05	52
Regularity of heat periods...............		Fair	18	Fair	18
Interval between heats.	Days	29.4	68	29.8	76
Services required for conception..........	Number	1.7	31	1.9	30
Length of gestation....	Days	281.1	16	281.6	16
Cases of retained placenta..............	Number	2	16	2	16
Abortions............	Number	1	..	1	..
Calves born dead......	Number	0	..	3	..
Calves died some time after birth..........	Number	1	..	0	..

sequently are not represented in the records for Table 2. Here the evidence seems about evenly divided. The cows receiving vitamin A supplement averaged a shorter interval between heats, a shorter time from calving to first heat, a slightly smaller number of services and half as many calves born dead. On the other hand, they had a somewhat higher incidence of retained placenta, more abortions, and all the cases of calves which died a while after birth.

The heifers (see Table 4) which received extra vitamin A did not gain quite as much as those not receiving it; regularity of heat was about the same; and number of days between heats and number of services required were not greatly different, although favoring slightly the group which received supplemental vitamin A.

The record of the calves in Table 5 is consistently slightly in favor of the group whose dams received the vitamin supplement. They averaged slightly heavier at birth and were in slightly better condition. Those saved for the herd showed a slightly greater average gain in weight at the end of a month. Also there were less than half as many calves born dead; and, since there were nearly twice as many calves from this group as from the group not receiving the vitamin A supplement, the difference is somewhat greater on a percentage basis (2.8 percent born dead as contrasted with 14.0 percent).

TABLE 5. — RECORD OF CALVES DROPPED DURING THE EXPERIMENT.

		Dams Receiving Vitamin A Supplement		Dams not Receiving Vitamin A Supplement	
		Records during Experiment	Number of Records	Records during Experiment	Number of Records
Number of individuals.			108		57
Average condition of calves at birth......		Good	108	Fairly good	57
Average birth weight of all living calves......	Pounds	75.3	104*	73.4	49
Average birth weight of calves saved........	Pounds	76.3	64	76.3	31
Average weight at 1 month of calves saved	Pounds	105.3	..	105.0	..
Average gain in a month	Pounds	29.0	..	28.7	..
Calves born dead......	Number	3	..	8	..
Sex of calves:					
Male..............	Number	53	..	29	..
Female.............	Number	55	..	28	..

*There were 105 living calves. Through an oversight, one was not weighed.

The weights given have been corrected for breed differences in the make-up of the groups. Differences due to varying sex ratio were also checked, but were not sufficient to be of any significance.

Wherever possible, statistical analyses have been made of the foregoing data. The results show that taken individually none of the differences between the groups are significant. However, when the evidence is considered as a whole, the trend although slight is in favor of the group which received the vitamin A supplement. Twenty comparisons of various phases of reproductive function are available for the duration of the experiment and have been summarized in the foregoing tables. Of these, eleven favor the group receiving the supplement, six favor the other group, and three are evenly divided.

So far as growth and reproduction are concerned, the effect of the supplement seems to be reflected principally in a higher birth weight of the calves and in a smaller percentage of stillborn calves.

Effect on Milk Production

The influence of the vitamin A supplement on milk production has also been noted. Records are available for 72 complete lactation periods during the experiment. About half of the cows were in the herd previously and their records for 56 complete lactation periods previous to the commencement of the experiment are available for comparison with those secured later. The results are summarized in Table 6.

TABLE 6. — EFFECT OF THE VITAMIN A SUPPLEMENT ON MILK PRODUCTION

	Average Daily Production per Cow, in Pounds (Corrected*)	
	Group Receiving Vitamin A Supplement	Group not Receiving Vitamin A Supplement
1. Records of all cows during the experiment....	35.43	30.95
2. Records during the experiment of cows in the herd previously........................	34.84	28.35
3. Records of Group 2 previous to the experiment .	32.94	32.21
4. Records during the experiment of cows not in the herd previously.....................	35.41	36.11

*All milk production records have been corrected individually to the usual standard basis; i. e., to twice-a-day milking, 4 percent fat, 305-day lactation; also for age and for length of pregnancy during lactation. Only the corrected values for average daily production are given in the table.

The apparent effect on milk production as indicated by these results is decidedly favorable to the vitamin A supplement. There is, however, no good reason to believe that the supplement would cause such large differences in production, and when the records are carefully analyzed it is found that most of the effect is only apparent. None of the differences are significant, being due to unavoidable irregularities in the make-up of the groups with respect to breed. Since a satisfactory correction for breed differences cannot be applied, the only alternative is to present the results corrected so far as possible, and explain the reason for most of the apparent difference.

It should not be concluded from the preceding paragraph, however, that the supplement was without effect on milk production. There is good reason to believe that it did have some positive effect in this respect as indicated by the following evidence:

1. When the results are broken up into sub-groups according to breeds the differences in production during the experiment are in favor of the supplement for all five breeds of cattle, and this situation holds true whether all the cows in the experiment are considered, or only those that were in the herd previously. The fact that none of the breed differences in themselves are of significance, is due in part to the comparatively small number of records for each breed. The trend is certainly suggestive of positive effect.

Of more significance is the fact that the breed records previous to the experiment do not show any such definite trend in favor of the group that later received

TABLE 7. — CORRECTED MILK PRODUCTION BY BREEDS, BOTH BEFORE AND DURING THE EXPERIMENT (COMPLETE LACTATIONS ONLY).

	Average Daily Production per Cow, in Pounds	
	Group Receiving Vitamin A Supplement	Group not Receiving Vitamin A Supplement
1. Records of all cows during the experiment		
a. Shorthorns	25.93	24.96
b. Ayrshires	37.01	30.98
c. Holsteins	40.93	39.70
d. Guernseys	30.93	30.31
e. Jerseys	31.00	20.59
2. Records during the experiment of cows in the herd previously		
a. Shorthorns	27.44	26.09
b. Ayrshires	36.32	28.78
c. Holsteins	41.41	33.67
d. Guernseys	31.84	30.31*
e. Jerseys	30.71	20.59*
3. Records of group 2 previous to the experiment		
a. Shorthorns	30.94	27.40
b. Ayrshires	35.74	41.57
c. Holsteins	33.46	36.42
d. Guernseys	27.60	31.51
e. Jerseys	33.16	26.55

*It so happened that all the Guernseys and Jerseys in group 1 not receiving the supplement had been in the herd previously; hence the identical values for these breeds in groups 1 and 2.

the supplement. Average production previous to the experiment for three of the five breeds represented was greater in the group that later did not receive the supplement than it was in the group which received it, although not significantly so. Table 7 will aid in making clearer these differences and trends.

2. The average production of individual cows before and during the experiment has also been compared, with the following results:

	Group Receiving the Supplement	Group not Receiving the Supplement
Number of cows showing an increase in production during the experiment over their previous production	18	1
Number of cows showing a decrease in production	10	8
Percentage of total number in group showing an increase	64.3	11.1

In fairness it must be stated that, had there been a larger number of complete lactation records available for the group not receiving the vitamin supplement, the result might have been less favorable to the other group. Nevertheless straws show which way the wind blows.

Everything considered, it seems that the vitamin supplement had a favorable effect on milk production. It is to be regretted that, for reasons already given (see page 8), the extent of this effect cannot be definitely stated.

The question may be raised as to how this favorable effect made itself manifest in increased production. It is believed that it was brought about by a raising of the level of persistency in milk flow in those individuals receiving the supplement. In support of this contention the average lengths of lactation for the several groups and sub-groups of cows are listed in Table 8.

The significant feature of these lactation records lies in a comparison of the figures for groups 2 and 3, before and during the experiment. Previous to the experiment, those cows later receiving the supplement had an average lactation period one week shorter than did those which later did not receive the supplement; but this relationship was changed during the experiment so that the cows receiving the supplement had an average lactation period twenty days longer than that of the other group. It should be noted that this greater persistency by the cows receiving the supplement was in spite of the fact that these cows averaged thirty days longer in calf during their lactation than did the others; whereas before the experiment they carried a calf, while milking, on an average eleven days less than the other group did.

The same general relationship was true also for the young cows in group 4; i. e., a greater persistency in milk yield among those receiving the supplement, despite a somewhat longer period in calf while milking. It may be fairly contended that possibly those young cows receiving the supplement had a better inheritance for persistency than those that did not receive it, but the results are presented here nevertheless as showing the same general trend as those for group 2, against which, as shown above, such a contention does not hold.

The data for group 1 are listed only for the sake of completeness. Since they are a composite of those for the other groups, it naturally follows that they would show the same general trend.

TABLE 8. — LENGTH OF LACTATION AND GESTATION PERIODS DURING AND PREVIOUS TO THE EXPERIMENT.

	Average Length of Lactation (Days)		Average Length of Time in Calf during Lactation (Days)	
	Group Receiving Vitamin A Supplement	Group not Receiving Vitamin A Supplement	Group Receiving Vitamin A Supplement	Group not Receiving Vitamin A Supplement
1. Records of all cows during the experiment........	299	286	200	161
2. Records during the experiment of cows in the herd previously............	305	285	200	170
3. Records of group 2 previous to the experiment..	322	329	216	227
4. Records during the experiment of cows not in the herd previously........	290	285	194	150

Effect on the Fat Content of the Milk

Regular monthly herd tests for butterfat have made it possible to study the influence of the vitamin A supplement in this respect also. Because of the lack of uniformity in breed make-up of the groups, already referred to in the section on milk production, the only way that possible effect on fat test can be studied is to compare by breed sub-groups the records before and during the experiment of those cows previously in the herd. This comparison is summarized in Table 9.

The results in Table 9 show that for all breeds, regardless of the group in which the cows were placed, there was a lowering of the average fat percentage during the course of the experiment. The drop in test is not appreciable except in two cases — the Shorthorn and Jersey sub-groups which did not receive the vitamin A supplement. These two fell off enough so that the average for the whole no-supplement group dropped more than twice as much as the average for the group receiving the supplement.

The differences on the whole are so small that it has not been deemed worth while to analyze them statistically. It is believed that they cannot be of any significance, and it seems safe to conclude that the vitamin supplement did not affect the fat content of the milk. Attempting to explain the general lowering of fat percentage probably would be futile. Some authorities might attribute it to increasing age, but none of these cows were past their prime when the trial was completed. It is well known that age has little if any effect on fat test until a cow gets well along in years. (See Eckles: Dairy Cattle and Milk Production. Revised Edition 1931, pages 425-6).

TABLE 9. — EFFECT OF THE VITAMIN A SUPPLEMENT ON THE FAT CONTENT OF THE MILK.

	Group Receiving Vitamin A Supplement		Group not Receiving Vitamin A Supplement	
	Average Fat Test	Number of Records	Average Fat Test	Number of Records
1. Records during the experiment of cows in the herd previously				
a. Shorthorns	4.05	5	4.08	5
b. Ayrshires	4.09	8	4.09	2
c. Holsteins	3.62	11	3.62	5
d. Guernseys	4.82	7	5.13	6
e. Jerseys	5.96	12	5.34	4
Weighted average fat test	4.59		4.49	
Total number of records		43		22
2. Records of group previous to the experiment				
a. Shorthorns	4.15	5	4.36	4
b. Ayrshires	4.19	8	4.10	2
c. Holsteins	3.67	11	3.70	4
d. Guernseys	4.90	6	5.24	6
e. Jerseys	6.02	12	5.71	3
Weighted average fat test	4.67		4.69	
Total number of records		42		19

NOTE: It should be clearly understood that in all cases the records before and during the experiment are for identical cows. The larger number of records in some instances for the period covered by the experiment is due to the fact that occasionally only one record was available for a cow previous to the experiment, while during the experiment two records were available in almost all cases.

Effect of the Supplement on the Vitamin A Content of the Milk

This topic is perhaps of most interest from the standpoint of human nutrition, but it may also be of significance in the successful rearing of calves. Biological assays of the milk from the two groups of cows were made at two different times during the course of the experiment — once during the winter of 1936 and again during the winter of 1937.[4] The tests were made on three-day composite samples of the milk. Results appear in Table 10.

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[4] Acknowledgement is made to Dr. W. S. Ritchie and Dr. W. B. Esselen of the Experiment Station staff, who made the assays for carotene in feeds and vitamin A in milks.

TABLE 10. — VITAMIN A POTENCY OF MILKS.

	U. S. P. units of Vitamin A per quart of milk	
	1936	1937
Cows receiving the Vitamin A supplement..........	2025	3596
Cows not receiving the supplement................	448	2744

It seems clear from these results that the roughage fed during the winter of 1937 must have been considerably superior to that fed during the winter of 1936, from the standpoint of carotene (vitamin A) content; also that the supplement was somewhat more effective in raising the vitamin A level of the milk the first year than it was the second.

In any case it seems apparent that (1) the supplement did increase somewhat the level of vitamin A in the milk, but that (2) the efficiency of the cows in transmitting the vitamin A of the supplement or the carotene of the feed to their milk was very low, barely over 2 percent at best, about one third of one percent at worst. This lack of efficiency on the part of cows has been shown by other investigators also, and seems to be characteristic.

Summary

The effect on growth, reproduction, and milk production in dairy cattle, of adding to the grain ration a vitamin A supplement in concentrated form, was studied during a period of twenty-two months.

The entire dairy herd at the State College (young calves and bulls excepted) was included in an extensive feeding trial, one group of cows and heifers receiving the vitamin A supplement, while another group under the same conditions of feeding and management did not receive it.

Careful records were kept of growth and reproductive function in the heifers and of reproductive function in the cows. Milk records of the cows were available as a matter of routine procedure, also monthly butter fat tests. Vitamin A assays were made of feeds and milk. Reproductive records, milk yields, and fat tests previous to the experiment for those cows previously in the herd, were also available for comparison.

Results may be summarized as follows:

1. The supplement was without effect on the growth of heifers past the calfhood stage.

2. It had a slight, but not significant, favorable effect on reproductive function in cows and heifers. This was reflected chiefly in a higher weight at birth of the calves born to the group of cows receiving the supplement and in a smaller percentage of stillborn calves in that group. All phases of reproductive function considered, the trend, although slight, was in favor of the supplement.

3. Everything considered, it had a favorable effect on milk production, although for reasons given in the text the extent of this effect cannot be definitely stated. This effect seems to have been brought about through an increased persistency in milk flow by those cows receiving the supplement.

4. The average butterfat content of the milk does not seem to have been affected, either favorably or adversely.

5. The vitamin A content of composite milk samples from cows receiving the supplement was somewhat higher than that of similar samples from cows that did not receive it. The efficiency of transfer of the vitamin from feed to milk was very low in all cases.

Conclusions

If New England dairymen could always feed good quality alfalfa hay through the winter and if they could be sure of having well-preserved corn silage stored before frost, it is probable that their cows would not need additional vitamin A. But since for most of them such a state of affairs is not attainable, some other source of the vitamin must be relied upon; and it seems justifiable to recommend for average New England conditions the inclusion of some form of supplemental vitamin A in the rations of dairy cattle during that period of the year when they are not on pasture. The practice will be of most value on those farms where silage is not fed and the hay is of poor quality.

Grass silage is a partial answer to the problem, but only partial because much of the grass silage stored on New England farms fits into the farm program best as a late summer supplement to short pastures. Carrots are a wonderful source of the vitamin, but they are costly to grow and, because of the price they bring for human food, it is only rarely that they can be fed to cattle to advantage.

About the only alternative left, then, is a concentrated source of the vitamin incorporated in the grain mixture. Since it has been shown that cod liver oil fed as such tends to lower the butterfat percentage in milk, the plain oil cannot be recommended for cows in milk. Fortunately it is possible by adding a concentrate of the vitamin to cod liver oil to make it much more potent than the plain oil; and such a product, because of the much smaller amount used, does not affect the butterfat test unfavorably when it is fed to cows. Such a fortified oil was used in the work here reported.

It must be admitted that the results here obtained, although favorable to the supplement in their general trend, were not marked. On the other hand, it should be borne in mind that these cows were on better than average rations, some of them being fed for Advanced Registry records. It seems reasonable to assume that response to the supplement might be more marked under average farm conditions than it was in this case.

All things considered, it is our opinion that the slight additional cost of grain mixtures fortified with a vitamin A concentrate is cheap insurance against troubles due to deficiency of this vitamin, particularly when the roughage is of poor quality.

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Blueberry Culture in Massachusetts

By John S. Bailey, Henry J. Franklin,

and Joseph L. Kelley

Although the wild blueberry is native to New England, there was little interest in its improvement until cultivated varieties attracted attention. Since then, there has been a demand for information on varieties and cultural methods which this bulletin aims to supply.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

BLUEBERRY CULTURE IN MASSACHUSETTS

By John S. Bailey[1], Assistant Research Professor of Pomology, Henry J. Franklin, Research Professor in Charge of the Cranberry Station at East Wareham, and Joseph L. Kelley, Technical Assistant at the Cranberry Station

Blueberries, although not peculiar to the New England States, grow wild here in great profusion. Massachusetts has received her full share of this gift from Mother Nature.

But man, being hard to please, was not satisfied with Nature's gift. He wanted sweeter and larger berries. To satisfy this desire, the late Dr. F. V. Coville of the United States Department of Agriculture started his pioneering work on the culture and breeding of blueberries, work which laid the foundation for their commercial cultivation. He produced and named several varieties with fruit larger and more handsome than that of their wild ancestors. These varieties were developed from the highbush or swamp blueberry, *Vaccinium corymbosum* L., and have the growth habit, and soil and climatic requirements of that species. Dr. Coville received valuable help from Miss Elizabeth C. White of New Lisbon, New Jersey, who provided much of the first stock for his breeding work and was a pioneer in developing commercial production.

Although relatively few acres of improved blueberries have been planted in Massachusetts, there is a fast growing interest in their culture which has led to a large demand for information about them. This bulletin is meant to serve as a guide to those interested in blueberry growing. To make it more useful, suggestions are given for better management of wild blueberry lands.

Soil Requirements

Because the highbush blueberry commonly grows in low, swampy places, many people have the false notion that this blueberry thrives best in such locations. It grows there because it tolerates such conditions better than many other plants and so has less vegetation to compete with. Removed from such competition, the swamp blueberry thrives much better on a fertile soil than on a poor one.

The ideal blueberry soil is fertile, has a plentiful and continuous water supply, is well drained and aerated, is well supplied with organic matter, and is acid.

Since success with cultivated blueberries depends on growing large berries, the plants must be kept highly vigorous. The need for strong growth is all the greater because of the severe pruning required, as will be explained later. A fertile soil is therefore important.

A steady, adequate water supply is essential. A soil which dries out, even for short periods, will never do for blueberry growing unless water is somehow supplied. However, too much water is as bad as too little. Although blueberries will tolerate standing water from the first of November to the first of April, excess water short of flooding may do serious damage. When a poorly drained soil freezes, the plants are lifted and their roots broken (Fig. 1). Surplus water during the growing season is always harmful. The water table (the upper limit of the part of the ground that is saturated with water) in a blueberry soil must be at least 14 inches below the surface. If it is not, the land must be drained before blueberries are planted.

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[1] The authors wish to thank Mr. F. E. Cole of the Worcester County Extension Service for supplying the information for the section on the improvement of wild highbush blueberries. This information was obtained from experiments started by Mr. Herbert Reiner, formerly with the Worcester County Extension Service. This bulletin supersedes Bulletin 317, which was published in 1935 and 1936.

How essential organic matter is under all soil conditions, is not known. With light sandy soils it is very necessary; with heavier, more fertile soils it may not be. However, experiments and experience indicate that the plants grow much better if the soil has a plentiful supply of organic matter.

Blueberries, for their best development, require an open, well-aerated soil. Wild bushes in swampy places grow on hummocks where their roots are out of water and well aerated during the growing season. Even where moisture conditions are favorable, blueberries thrive best in an open, well-aerated soil.

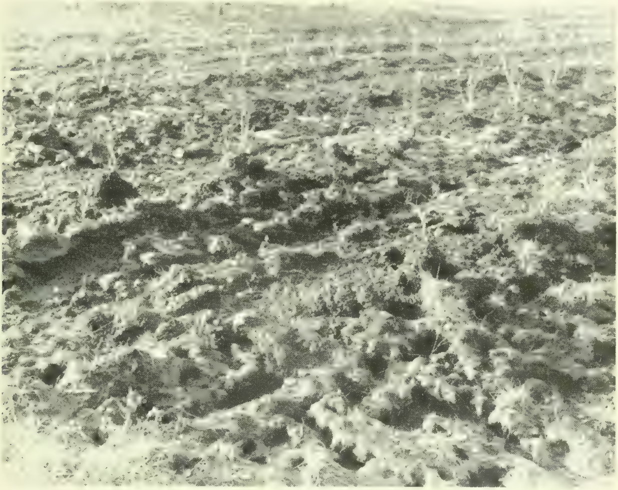

Figure 1. Blueberry Plants Lifted Out of the Ground by Freezing of the Soil. This location is too wet. It should have been drained before the plants were set.

The blueberry needs an acid soil but just how acid is uncertain. The soils in thirty blueberry plantings showed a pH range of 4.3 to 5.9 (lower pH values mean higher acidity and vice versa). The variation in growth on these different soils was more closely correlated with one or more of the other soil factors than with soil acidity. However, when the soil reaction is about pH 5.8 or above, the leaves of the plants may develop a mottled appearance (Fig. 2) due to inability of the plant to get enough iron for healthy growth. This condition occurs most often on light, dry soils, low in organic matter. Most unlimed soils of Massachusetts are strongly acid (pH 4 to 5.5). Small areas of limestone origin in Berkshire County have surface soils which are only slightly acid and subsoils even less acid or neutral.

This State has much land suitable for blueberries. A growth of wild swamp blueberry, leatherleaf, cranberry, white cedar, or red maple indicates a favorable

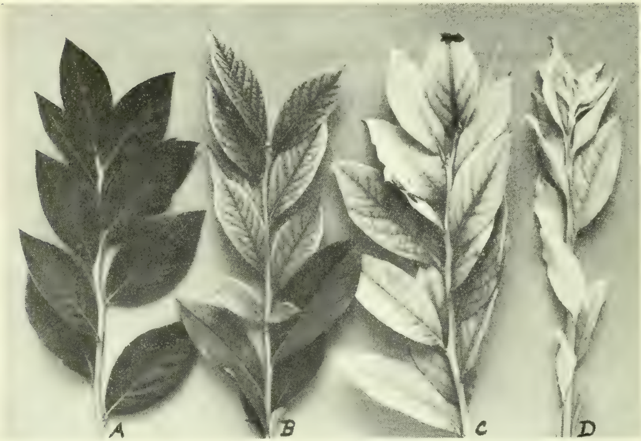

Figure 2. Iron Chlorosis of the Cultivated Blueberry.
A, Healthy shoot; B-D, increasingly severe stages of chlorosis.

soil. Low meadows are often suitable if there is adequate air and water drainage. Hillsides may be used if the soil conditions are right and soil erosion is prevented. If erosion is not prevented, serious gullying may occur (Fig. 3). Many abandoned cranberry bogs in the southeastern part of the State probably would be satisfactory. Land previously used for garden crops is usually unfit for blueberries because it is not acid enough. It often may be made suitable by mixing with it woodland turf, fallen leaves, or peat, using at least a bushel per plant.

Preparation of Land

If the land has not been under cultivation, it must be cleared of all trees, stumps, and bushes. If it is low and wet, it must be drained so that the water table will remain at least 14 inches below the surface. Low spots should be filled in or drained so there will never be standing water during the growing season.

After clearing and draining, the field should be plowed and harrowed to thoroughly mix and condition the soil. Thus prepared it should be kept fallow for a year, especially if a sod harboring white grubs has been plowed in. Occasional harrowing while the land is lying fallow will improve its condition and increase the chances of success with the plants.

Selection of Varieties

Although the blueberry is new among cultivated fruits, desirable varieties are already available. The bush of the ideal variety is able to produce a heavy crop and abundant new growth annually. It is easy to propagate and prune, disease resistant, especially to mummy berry and Phomopsis gall, and hardy in winter. An upright habit of growth makes picking easy and keeps the berries out of the dirt.

The berries of the ideal variety are large and uniform in size throughout their season.[2] Blue color, plenty of bloom over the surface, and pleasing flavor are desirable; good keeping and shipping quality are essential. The sepals, which remain as part of the fruit, are small and closely appressed. The skin is as thin and tender as is possible without sacrificing shipping quality. The berries hang to the bushes well and separate from the stem with a small scar, and without tearing of the skin.

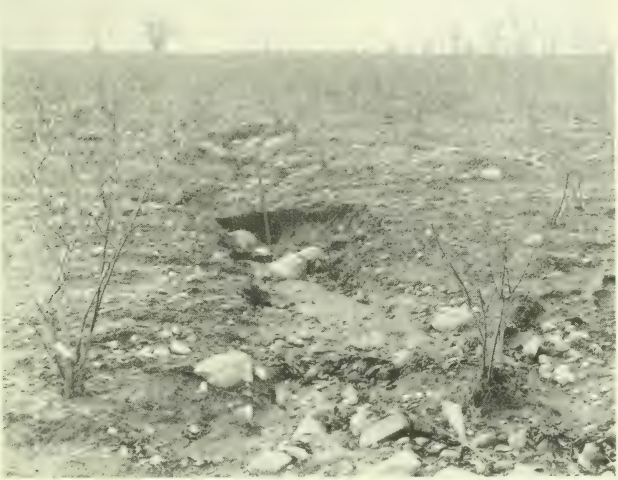

Figure 3. Serious Gullying in a Blueberry Field Caused by Heavy Rains in September 1938. This should have been prevented; it is hard to stop.

In Massachusetts early varieties, because of competition from cultivated berries from farther south, will probably be less profitable than late ones. In some localities their crops may be reduced by spring frost oftener than those of later varieties. However, early varieties have a place in some plantings to start the season's local or roadside trade.

Two varieties are recommended for commercial planting in Massachusetts: Pioneer and Rubel.

Pioneer is a mid-season variety, ripening from middle to late July. It produces large crops of berries superior in appearance, flavor, and keeping quality. The bush is of medium height and fine appearance for ornamental planting. It is hard to propagate and costly to prune.

Rubel is a late variety, ripening a few days after Pioneer. It is a good producer. The berries are only fair in size, but their quality is good and they ship well.

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[2] Large berry size has been very properly stressed by those selecting and breeding blueberry varieties. It adds to the attractiveness of the fruit and, other things being equal, increases yield and reduces cost of picking. But yield and cost of growing, though equally important, have not had the attention they deserve.

The bush is tall, upright, well shaped, vigorous, and easy to propagate and prune. Because of less competition from the South, this is one of the most profitable varieties in this State.

CABOT, for those wanting an early variety, ripens a week to ten days ahead of Pioneer. The berries are large, fair flavored, and good shippers. The plants are low, spreading, and not so vigorous as those of Pioneer and Rubel. They are hard to propagate, costly to prune, and very susceptible to Phomopsis gall. They yield fairly well.

The following varieties are recommended for trial:

STANLEY is a very promising mid-season variety. The fruit is large, handsome, and excellent in flavor. The bush is upright, vigorous, productive, and easy to propagate and prune.

JERSEY ripens with Rubel. The bush is very vigorous, productive, and easy to propagate and prune, but does not sprout from the base as freely as is desirable. The berries have good color, size, and keeping quality, and good flavor when well ripened. The stems are long, making the cluster so open that the berries are easily picked. The calyx lobes protrude, detracting somewhat from the appearance of the fruit.

WAREHAM is a promising variety ripening a week after Rubel. The bush grows vigorously, is easy to propagate and prune, and yields heavily. The berries develop to good size throughout the season, keep fairly well, and have good flavor, but are less attractive than the fruit of some varieties because of their dark color.

Propagation

An ordinary cold frame makes a satisfactory propagating frame. About six inches of propagating medium is necessary and it should be leveled. The best medium is a mixture of about equal parts by volume of sphagnum peat and sand. Since American peats vary, unless one known to be good for propagating can be obtained, it is better to use imported peat of the grade GPM. Peat must be wet before use. It is hard to wet with cold water but hot water wets it easily. A quarter inch of clear sand over the bed reduces weed trouble and facilitates watering. A wire screen placed under the bed prevents root injury by grubs.

The successful handling of the propagating bed depends on the proper control of five factors: aeration of the propagating medium, moisture in the propagating medium, humidity in the propagating frame, light, and temperature. The first three are closely associated and practically are controlled together.

Lack of aeration in the propagating medium, because it is too compact or too wet, causes the cuttings to rot at the base and die. Aeration is sufficient if there is good drainage below the propagating bed to eliminate excess water and if there is ventilation over the bed. Watering should be heavy when it is necessary. Enough moisture will be held in the propagating medium to keep the cuttings from drying out and to assure proper humidity over the bed.

It is important to maintain humidity over the propagating bed because of the nature of the rooting process with blueberry cuttings. Since they make a top growth before they develop roots, the air above the bed must be moist to prevent the new growth from wilting. Humidity can be maintained by using glass sash over the beds; but unless constant attention is paid to ventilation, the propagating medium may become water-soaked.

The propagating bed must be kept from becoming too hot by shading and ventilation. When the cuttings have grown leaves, they begin to make food for themselves if they have light enough. Therefore, they should be given all the light they will stand by removing the shades on cloudy days. However, the shades must be put back at once if the sun comes out, for even a few minutes of bright sunlight may do great harm.

The cuttings may be taken during the winter and stored in moist sphagnum or two-year-old sawdust (newer sawdust heats) till spring. Or the bushes may be pruned late in March and the cuttings, which must not be allowed to dry, taken at once from the prunings.

Cuttings are made from wood of the previous season's growth, and must have no fruit buds. Weak, spindling cuttings are not desirable as plants grown from them are usually small and slow in growth. Cuttings over a quarter inch in diameter seem to root less readily than medium-sized ones; but when they do root, they usually make large, vigorous plants. The best length is three to four inches, with the top cut just above a bud and the bottom cut below and as close to a bud as possible, without injury to the bud. All cuts should be slanting and made with a very sharp knife so as to be clean and smooth.

The cuttings, beginning with the earliest varieties, should be put in the bed early in April before the buds begin to break. They may be set either at an angle of 45° or vertically, one inch apart, in rows two inches apart. If each cutting is placed deeply in the propagating medium with only the top bud out, usually only this bud will develop and a better plant will be produced.

After the cuttings have been set, the bed should be watered well and the sash put in place. The shades can be left off till the buds begin to break. This is desirable if the weather is cool. The shades may be of burlap or of slats supported about four inches above the sash. If they are made of slats, the proportion of slats to space should be about three to one. The cuttings must be watched closely during the rooting period. If any begin to rot, the bed must be aired by raising the sash slightly.

After the cuttings begin to root, the latter part of June, ventilation of the frames is started and is gradually increased until the sash can be removed altogether. The latter part of August, the light given the cuttings is gradually increased by removing the shades earlier in the evening and replacing them later in the morning till they are left off entirely.

The young plants may be left in the cold frame during the winter with hay, straw, or like material over them for protection. In the spring they are set in a nursery to grow for a year or two before they are put in the field. The nursery should be cultivated well, but not deeply enough to disturb the roots of the plants.

Planting

Planting should be done as early in the spring as the condition of the soil permits. The planting distance depends largely on the method of cultivation, the varietal characteristics of the plants, and the fertility of the soil. Plants on a very fertile soil grow larger and need more room than those on a less fertile one. Vigorous varieties need more space than less vigorous ones. Tractor equipment requires more room than hand or horse-drawn cultivators. Room for cultivating machinery need not be considered under a mulching system. In no case should the plants be set closer than 5 feet in rows 8 feet apart. So spaced, 1,089 per acre are required. The rows must be 10 feet apart for cultivation with a tractor.

It seldom pays to set plants under two years old. The saving in the cost of younger plants is usually offset by higher mortality the first year in the field. Each plant from the nursery has the roots in a ball of earth. This should be disturbed as little as possible in planting. The holes for the plants should be dug large enough to place the roots without crowding and deep enough to put about an inch of the stem below the soil surface.

Blueberry varieties are self-unfruitful, or nearly so, under some conditions. Therefore, it is best to plant at least two varieties. They should be set in alternate rows if they are equally desirable. If not, at least every fourth row should be different.

Soil Management

Blueberry plantings are usually kept cultivated from early spring till about mid-August. Cultivating after that may cause late growth and make the plants susceptible to winter injury.

Since blueberries are shallow-rooted, cultivation should not be deep, especially close to the plants. As a result of their experiments in New Jersey, Beckwith and Doehlert (2) recommend cultivating to an average depth of three inches between the rows but no nearer to the plants than the ends of the branches. To check weeds close to the plants, they advise hand hoeing or very shallow cultivating with an acme harrow. This agrees with experience in Massachusetts that tillage is necessary to keep the soil from becoming packed and poorly aerated but that deep cultivation close to the plants is harmful.

A mulching system for blueberry plantings has been satisfactory in some places. This makes cultivation unnecessary, adds organic matter to the soil, and conserves moisture. But mulch may be costly and hard to get, dry mulch is a fire hazard, and some mulches greatly increase the danger of injury by mice. Pine needles, fallen leaves, and peat are all excellent mulching materials. Sawdust or shavings may be used. Straw and waste hay are too attractive to mice. Enough mulch should be used to keep weeds down.

Fertilization

Blueberry plants respond readily to fertilization. Although nitrogen generally affects growth and yield most, experiments in New Jersey (2) indicate that a complete fertilizer is desirable because nitrogen used alone causes excessive shoot growth.

Young blueberry plants are easily hurt by too much fertilizer. No fertilizer is needed the year the plants are set. A small handful well spread out around each plant is enough the year after planting. The next year a little more may be used. The fertilizer is less likely to cause injury if it is mixed with about three times its weight of dry sand to facilitate spreading.

The third year and thereafter the fertilizer can be scattered broadcast between the rows and the amount gradually increased till five or six hundred pounds per acre are used when the bushes begin to bear. This heavy fertilization of the bearing bushes is recommended because vigorous shoots produce the largest and best berries and because abundant growth is needed to replace the wood removed in pruning.

The following mixture, which analyses about 7-8-7, is recommended:

Nitrate of soda	450 pounds
Calcium nitrate	450 pounds
20% Superphosphate	800 pounds
Sulfate of potash	300 pounds

Since the New Jersey Agricultural Experiment Station has obtained very good results by splitting the fertilizer application, it is recommended that half the fertilizer be applied the middle of May and the rest three weeks to a month later.

Cultivation after each application is beneficial.

The healthy growth of the bushes may not continue if the soil is not distinctly acid. It is better not to use soils with a pH above 5.5. Where they are in use, the acidity must be increased if possible. A fertilizer leaving an acid residue in the soil will help. Sulfate of ammonia is such a fertilizer. It may be applied

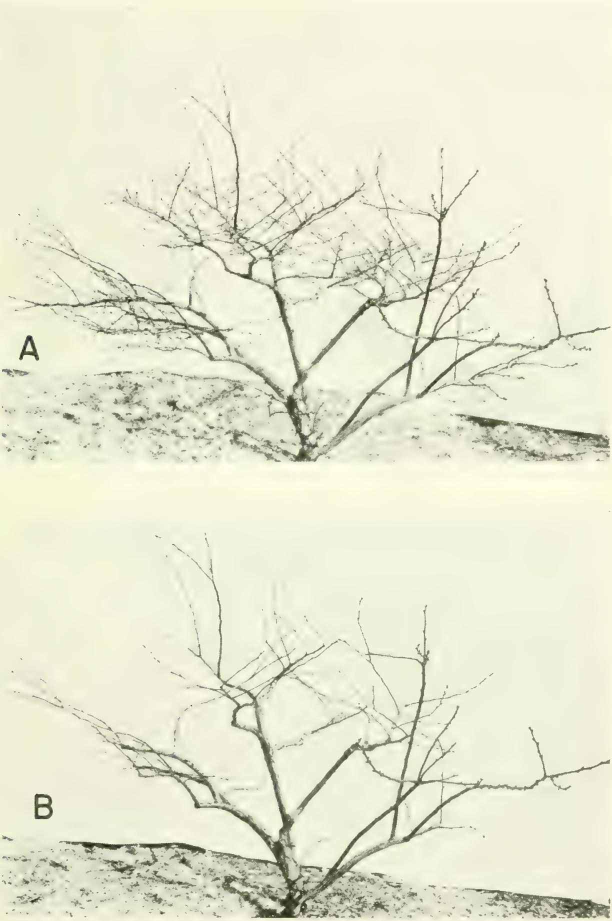

Figure 4. Pioneer. A. Before Pruning; B. After Pruning.
Note bushy, spreading growth which requires more detailed and costly pruning than Rubel.

alone, but a better plan is to substitute 710 pounds of it for the 900 pounds of nitrate of soda and calcium nitrate in the mixture given above. If this sulfate of ammonia combination is used, apply all the fertilizer at one time.

For those with a few bushes in the back yard, a ready-mixed, complete fertilizer is easiest to obtain and handle. Any good garden mixture or grass top dressing will do.

Pruning

Pruning is one of the most important operations in blueberry growing. Its purposes are to induce the bush to grow as many vigorous new shoots as possible, to prevent the bush from overbearing, and to stimulate the production of large berries. It must be done in the winter or early spring before growth starts.

The bushes need little pruning the first two years after planting. Only short, weak branches need be removed. Bearing during this period is detrimental because it reduces growth and delays the production of a commercial crop. Therefore, the fruit buds are removed during pruning. If any are missed, the flowers may be pulled off when the bushes bloom.

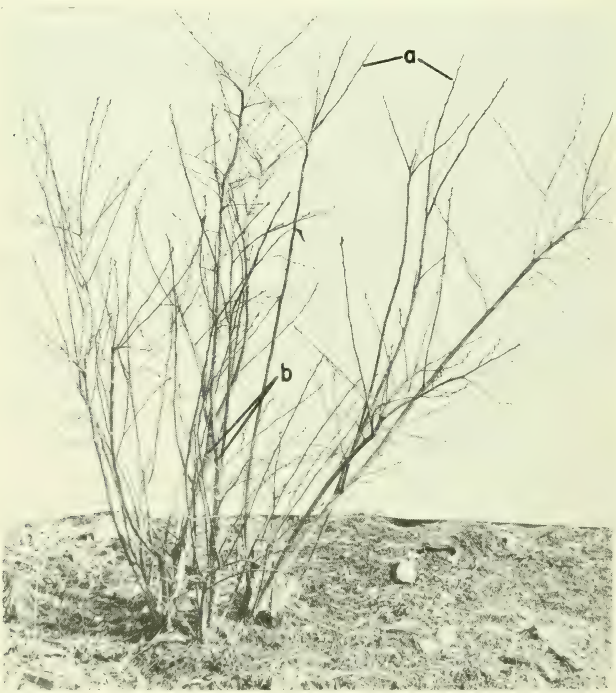

Figure 5. Rubel Before Pruning.
(a) Terminal shoots with fruit buds; (b) old stem to be cut out.

To prune bearing bushes correctly, one must know their bearing habit. The fruit buds are borne on the terminal part of the shoots. They form in the axils of leaves during the summer, remain dormant during the winter, then bloom and produce fruit the next summer. Fig. 7 shows shoots with their fruit buds (a) and leaf buds (b).

The pruning treatment of the different varieties varies according to the character of their growth. Those producing many shoots from the base require more thinning out of this growth than those with few such shoots. Varieties branching freely need more top thinning than those with few branches. Varieties whose shoots have fruit buds on the terminal two-thirds or three-fourths require more cutting back than varieties whose shoots have fruit buds on the terminal third or fourth only. The following outline of pruning practice is given as a general guide; not as a set of rules.

First, remove or cut back a few of the older stems such as (b) in Fig. 5. These stems after they are three or four years old, tend to produce short, weak shoots and small berries.

Second, remove all branches which are so near the ground that their fruit will get dirty.

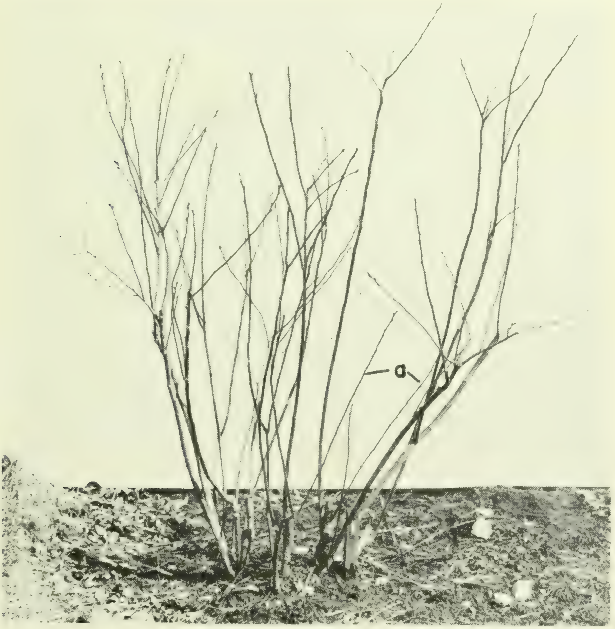

Figure 6. Rubel — After Pruning.
(a) Desirable new shoots growing from the base of the plant.

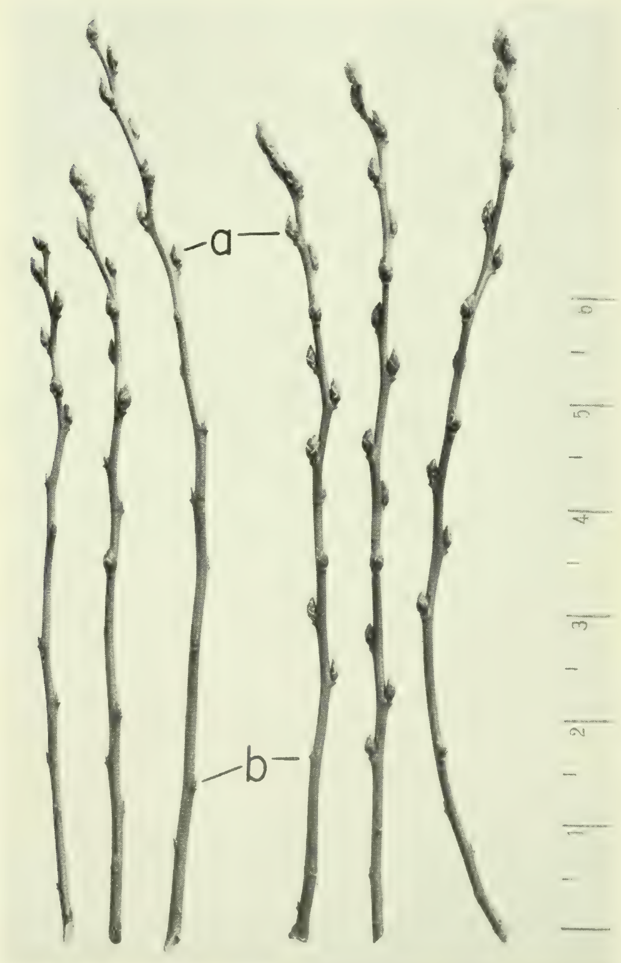

Figure 7. Terminal Shoots Showing Difference in Bearing Habit.
Note differences in size and numbers of fruit buds (a) and leaf buds (b).

Third, remove the shorter, weaker shoots to prevent crowding.

Fourth, cut back shoots with too many fruit buds. Three or four such buds on a shoot are enough because each bud produces a cluster of eight to twelve berries. If more buds are left, so many berries will develop that they will be small. Since some varieties, such as Cabot, grow many fruit buds relative to the number of leaf buds, their shoots must be cut back half to two-thirds. In Fig. 7 the three shoots on the right illustrate this condition. Other varieties such as Rubel, produce fewer fruit buds and need little or no cutting back. This is the condition of the three shoots on the left in Fig. 7.

Finally, study the needs of the plants. Cut freely to encourage new growth. If pruning for the first time, seek expert advice.

Insects and Diseases

The cranberry fruit worm, *Mineola vaccinii* Riley (5), sometimes attacks blueberries. It has become a serious pest of this fruit in Michigan. The mature worm is about half an inch long. It has a yellowish head and a green body sometimes tinged with red on the back. It often webs several berries together and works among them. It probably can be controlled by applying a derris dust (2 percent rotenone), at the rate of 100 pounds per acre toward the end of the blooming period.

The cranberry weevil, *Anthonomus musculus* Say, is sometimes a serious blueberry pest. The adult is a long-snouted beetle similar to the plum and apple curculios but smaller. The larva, about one-ninth inch in length, is a whitish, legless grub with a yellow head. The adults injure the flowers somewhat but the grubs do more harm in the berries. This insect can be controlled by spraying in the spring after growth starts but before egg laying begins, usually about May 10, with Bordeaux mixture and calcium arsenate made up as follows:

Stone lime	10 pounds
Copper sulfate	6 pounds
Water	100 gallons
Calcium arsenate	6 pounds
Fish-oil soap	4 pounds

The blueberry stem borer, *Oberea myops* Hald., (4) sometimes damages the bushes considerably. The beetles (Fig. 8B) lay their eggs (Fig. 8C) in young shoots about six inches from the tip. The female girdles a shoot in two places about half an inch apart and deposits an egg in a slit in the bark between these girdles. The tip of the shoot then dies, turns brown, and often breaks off at the top girdle (Fig. 8A). When the egg hatches, the young larva bores down the center of the shoot (Fig. 8D). It continues this boring for two or three years and may even reach the roots. The infested stem usually dies (Fig. 8E). If the borer gets into the roots, it weakens the whole plant and the leaves turn yellowish or reddish.

This insect can be largely controlled by having the pickers break or cut off the dead tips while gathering the fruit. If the egg has hatched and the larva has started to bore, the shoot should be cut off below the lower end of the tunnel. Infested stems missed in the summer will usually be found during pruning the following winter and should be removed then. As the larva is a legless grub and cannot crawl back to the bush, the infested shoots may be dropped on the ground. When the borers get into the roots, a piece of baling wire shoved down the tunnels will kill most of them.

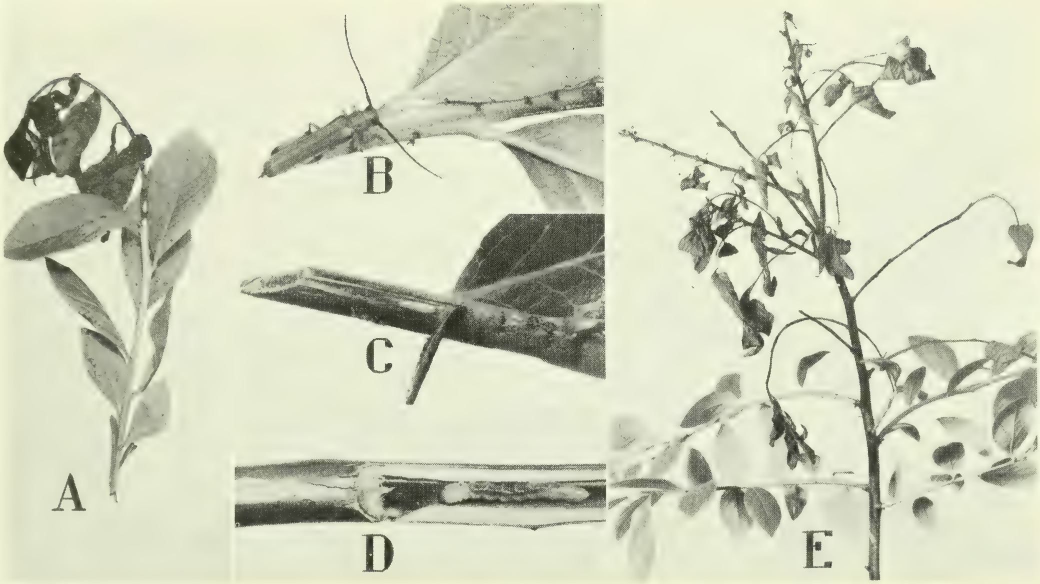

Figure 8. Blueberry Stem Borer.
A, Tip killed by egg-laying girdles; B, adult beetle; C, egg under bark; D, larva in tunnel; E, tip of branch killed by boring of larva.

The red-striped fireworm, *Gelechia trialbamaculella* Cham., does some harm to blueberries at times. The larvae, which are pale green when small, develop reddish brown stripes along the back and sides as they grow older until they appear to have a solid color unless closely examined. These worms fasten two or more leaves together and feed between them (Fig. 9). They make a tubular case of silk covered with brown castings. The injury to the older leaves is slight, but the stunting of new shoots resulting from the work of these worms on the terminal leaves is more harmful. A thorough application of the following spray about August 6, controls this pest:

40 percent Nicotine Sulfate	1 quart
Fish-oil Soap	4–5 pounds
Water	100 gallons

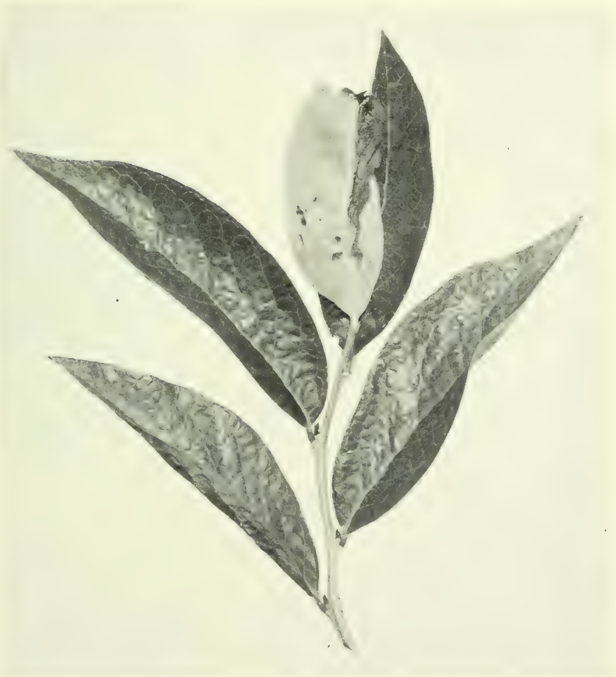

Figure 9. Red-Striped Fireworm Injury on Blueberry.

White grubs, the larvae of June beetles, *Phyllophaga* sp., injure blueberry plants seriously by eating the fibrous roots. They are usually troublesome in the propagating bed in dry seasons unless excluded by a fine metal screen, coarse gravel, or cinders under the bed. Plants set on land recently in sod are very subject to attack. This can be prevented by keeping the land fallow for a year before planting. Mature bushes sometimes become infested. A solution of sodium cyanide, 6 ounces in 100 gallons of water, applied around the crowns at the rate of 2 gallons per square foot, kills most of the grubs. **The cyanide is a deadly poison, and must be used with care.**

Caterpillars of the gypsy moth, *Porthetria dispar* (L.), sometimes do considerable damage but are easily checked by spraying with 6 pounds of dry lead arsenate in 100 gallons of water, about May 20.

Red-humped caterpillars, *Schizura concinna* Smith and Abbot, sometimes attack the blueberry. They feed in colonies, in August or September, and can strip a branch of leaves in a short time. If only a few are present, they can be shaken from the bush and crushed. Where they are abundant and the crop is entirely off, spray with lead arsenate, 4-5 pounds to 100 gallons of water. If the crop is not all harvested, use a heavy spray or dust of rotenone made up according to the manufacturer's directions.

The cranberry spittle insect, *Clastoptera saint-cyri* var. *saint-cyri* Prov., infests blueberry bushes occasionally. It is a sucking insect about an eighth of an inch long, appears usually in early June, and covers itself conspicuously with froth. It is controlled by spraying with:

Nicotine Sulfate	1 1/3 quarts
Fish-oil Soap	4 pounds
Water	100 gallons

The blueberry fruit fly or blueberry maggot, *Rhagoletis pomonella* Walsh (recently described as *R. mendax* by Curran), is a very troublesome pest of wild blueberries in some sections. It is present in parts of Massachusetts, but is not yet generally troublesome. The adult is a fly, similar to that of the apple maggot but smaller, appearing in late June and early July. The female lays her eggs under the skin of soft, overripe berries. The eggs hatch into small light colored maggots, 1/4 to 1/3 inch long, which work inside the berries. When infested berries fall to the ground, the larvae enter the soil where they pupate and pass the winter. The following summer the flies emerge to reinfest the fruit. They may be killed before egg laying begins by dusting with a commercial dust containing 0.60–0.75 percent rotenone, 70 pounds per acre, 8 to 10 days after the adults emerge, and again 7 to 10 days later. Keeping the berries picked so there will be no soft ones aids control. Removing wild bushes around the field also helps.

Mummy berry is the most harmful disease of cultivated blueberries. It is caused by a fungus, *Sclerotinia* sp., which rots and mummifies the green or partly ripe fruit badly in some years. In late summer the gray, dry, shriveled berries (Fig. 10) are found on the ground under infected bushes. Sanitary measures, such as removing wild bushes around the planting and brushing the mummied berries into the spaces between the rows and covering them by cultivation, will reduce this disease. Spraying with Bordeaux mixture 5-3-50 (5 pounds of copper sulfate, 3 pounds of stone lime or 5 pounds of hydrated lime, 50 gallons of water), at the beginning and again toward the end of the blooming period appears to be effective also.

A twig blight of blueberries is caused by a fungus, *Phomopsis vaccinii*, which causes a decay of cranberries(10). The fungus enters tender tips and travels down and kills the shoots. From the shoots it may enter older branches and girdle them so that all parts above the girdle die. Infected parts of plants should be cut out and burned. This disease is of minor importance.

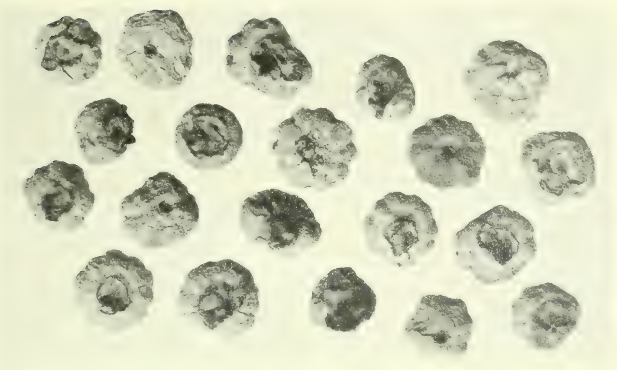

Figure 10. Mummy Berry Disease, Caused by a Species of Sclerotinia.

Phomopsis gall is due to a different species of *Phomopsis* from that causing the twig blight. It was formerly mistaken for crown gall, a bacterial disease. It appears as knotty swellings on the stem or branches (Fig. 11). It has been observed on several varieties, but Cabot, Concord, and Rancocas are the most susceptible. Wet soil favors it more than drier situations. It is spread by using cuttings from infected plants and is, therefore, mainly a nursery trouble. It can be eradicated by persistently removing and burning diseased bushes.

Witches broom, which gets its name from the type of growth it induces (Fig.12), is caused by *Calyptospora columnaris*, a rust fungus. It is perennial, but not serious, on both highbush and lowbush blueberries. This disease does not spread from blueberry to blueberry. It must infect an alternate host, the balsam fir, from which it spreads to the blueberry again. Its spread on an infected plant can be stopped by cutting off the diseased branch several inches below the affected part.

Birds, particularly robins and starlings, are among the worst pests of cultivated blueberries. They often take a large part of the crop in small plantings. Their depredations are not so marked in large fields. Inflated paper bags hung on strings so they will dance in the wind help keep birds away.

Harvesting and Marketing

Since the sale of cultivated blueberries at good prices depends on their attractiveness, they must be picked carefully. They must be neither too green nor too ripe. The stem end of ripe berries has a dark, rich blue color. A reddish tinge there indicates immaturity. Underripe fruit is sour and lacks blueberry flavor. Picking should be done every six or seven days. If done oftener than this, too many underripe berries are picked. If let go longer, there are too many overripe ones. Since the light blue bloom, which covers the berries and adds greatly to their appearance is easily rubbed off, they should not be handled much. They should be picked directly into the containers in which they are sold. For this reason one should hire pickers who can be relied on to grade well as they pick. Also they must have adequate supervision.

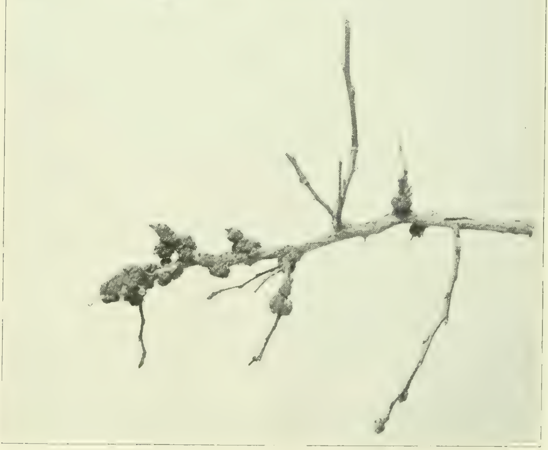

Figure 11. Phomopsis Gall, a Fungus Disease of the Blueberry, Caused by Phomopsis sp.

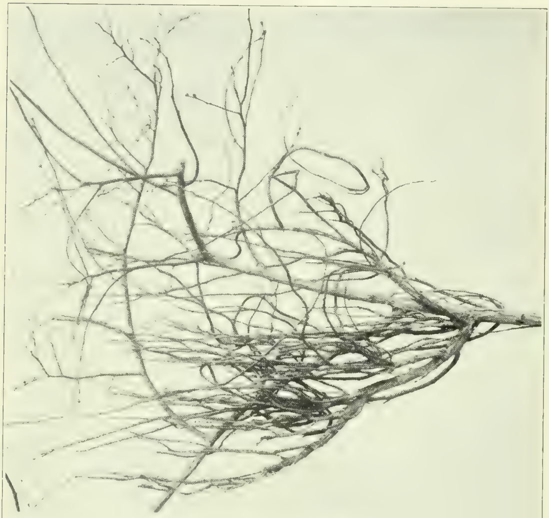

Figure 12. Witches Broom, Caused by the Rust Fungus, Calyptospora columnaris.

Little grading is done in Massachusetts as yet. In New Jersey, where the fruit is sold through a cooperative organization, all berries are graded to fixed standards. Grading is done partly by the pickers, who pick only sound berries, and partly in the packing shed, where the baskets are sorted according to the size of the berries they contain. Both quart and pint baskets are used.

Most of the cultivated berries are grown in New Jersey. There are small areas in Massachusetts, North Carolina, Michigan, and Washington. North Carolina growers are planting early varieties; New Jersey growers mid-season and late ones.

Prospective blueberry growers should consider the following: growing late varieties reduces to a minimum competition from berries shipped from farther south; growing varieties which are easily propagated and cheaply pruned keeps down production costs; care in the location of plantings helps prevent costly failures; location near main traveled roads facilitates roadside sale at retail prices.

The Improvement of Wild Highbush Blueberries

There are many acres of wild highbush blueberries in this State where the bushes are yielding much below their capacity because of lack of care. They can be made to double or triple their yield without great expense or labor.

In 1926 experiments were laid out on blueberry land in Hubbardston, Royalston, Westminster, Ashburnham, and Barre, Massachusetts, to try to increase the yield of wild bushes. The treatments were as follows: (1) all large trees and second growth shading the blueberries were removed, (2) the bushes were pruned, (3) fertilizer was applied. The pruning varied from removing a quarter of the bush to cutting it wholly to the ground. The fertilizers used were: nitrate of soda, ammonium sulfate, urea, calurea, cyanamid, 4-8-4, and nitrophoska. Different combinations of fertilizers and pruning were tried.

The following results were observed:

1. Removal of other vegetation increased the growth of the blueberry bushes.
2. Pruning, where not excessive, increased growth and yield. Removal of more than a quarter of the bush was too severe. Bushes cut to the ground yielded a few berries the third year thereafter but produced no commercial crop till the fourth year.
3. Fertilization increased the growth and yield of the bushes. These increases seemed to be due to nitrogen rather than to any other fertilizer element.
4. A combination of fertilization and pruning was much better than either alone.
5. The increase in production on the fertilized plots was due mostly to an increase in the number of berries per bush. It was impossible to obtain satisfactory comparative yield records under the conditions of the experiments. The bushes varied both in size and number per acre. Although the pickers were assigned to different parts of the field, they picked in the fertilized plots whenever possible, with or without permission. This is very good evidence of the better picking found there.
6. The berries on the fertilized plots tended to be larger, but the size of wild berries varies greatly and cannot be increased beyond limits set by inheritance.
7. Fertilized bushes had a marked tendency toward annual bearing, unfertilized bushes toward biennial bearing.
8. The berries on the fertilized plots were firmer during dry periods than those on unfertilized areas.

9. A terminal shoot growth of about ten inches was most favorable. Any increase in length up to ten inches increased yield. Longer shoots were apt to be too vegetative for maximum production.

These observations are the basis for the following improvement program:

First, remove all trees and bushes tall enough to shade the blueberries. This will often supply the winter's wood, thus making the labor serve a double purpose. If valuable timber trees are present, the owner must choose between blueberries and timber. The mowing of low bushes growing with the blueberries helps also.

Second, prune the blueberry bushes in winter or early spring before growth starts. Take out all dead wood first, then some of the oldest stems, cutting them off four or five inches from the ground. This can be done best with long-handled lopping shears.

Third, fertilize the bushes. Apply 200 pounds of nitrate of soda per acre, or some other nitrogenous fertilizer at a rate to give a like amount of nitrogen.

Fourth, select and tag the more productive bushes and give them special attention.

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MASSACHUSETTS

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Bulletin No. 359 May, 1939

Factors Affecting Fertility in Rhode Island Reds

By F. A. Hays and Ruby Sanborn

High fertility is a basic quality in a satisfactory breeding flock. This report includes results obtained over a fifteen-year period with large numbers of birds used in breeding for high egg production. Attention is given to the effects of a number of controllable breeding practices as well as to evidence regarding the inheritance of fertility.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

FACTORS AFFECTING FERTILITY IN RHODE ISLAND REDS

By F. A. Hays, Research Professor, and Ruby Sanborn, Research Assistant, in Poultry Husbandry

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Introduction

Fertile matings in domestic fowl may be defined as the bringing together by natural means of compatible sperm and compatible ova so that union of sperm and ovum takes place. Studies on fertility have shown that the process of fertilization is physiologically complex and that the fusion of a single sperm with a single ovum depends upon many coordinated functions.

Data at the Massachusetts Station indicate that a significant number of embryos die, probably during the first day of incubation, very likely due to zygotic lethals. Such embryos are too little developed to be recognized by ordinary candling methods so that the eggs are considered infertile. A cytological examination of the embryos in serial sections, however, shows definite embryonic development. It is therefore probable that the technique for classifying eggs as fertile or infertile needs to be modified.

Satisfactory fertility is a basic necessity in all poultry breeding operations. Progress in pedigree breeding depends largely upon high fertility to produce large families of birds for trapnest records and for the breeding test. Although experimental evidence indicates little or no association between high fertility and high hatchability, adequate reproduction very definitely depends on high fertility.

This report includes a study of the behavior of fertility in a breeding program extending over a fifteen-year period. Consideration is given to a number of controllable breeding practices as well as to evidence regarding the inheritance of fertility.

Data Available

Data used in these studies include 2,201 Rhode Island Red females ranging in age from one to five years and 305 males ranging in age from one to four years. The data are divided into two groups. In the late-hatched group the chicks were hatched at weekly intervals between March 25 and May 15 during the years 1922 to 1932. The records for 1926 were omitted because in that year the eggs were dipped into a creosote disinfectant before incubation, and this caused the death of many embryos. The early-hatched group was hatched in eight weekly hatches between March 4 and April 27 from 1933 to 1936. Fertility records of individual females are included only if they laid eight or more eggs during the breeding season.

1. Relation Between Temperature and Fertility

The mean of outside daily temperatures reported at the College during the days that the hatching eggs were laid for each hatch were calculated. In the late-hatched group these records began February 22 and in the early-hatched group, February 1. In both cases the first collection period and temperature record covered about ten days and all later collection periods and temperature records covered seven days.

The collection of hatching eggs for these weekly hatches covered about 52 days. During this period there was the normal increase in length of day, with something of an increase in the amount of sunlight. Since the birds were confined in the house, they had practically no direct sunlight; but they did have a somewhat longer feeding day as the season advanced, since no artificial lights were used. It is believed, however, that wide fluctuations in temperature during the period and the prevailing low temperatures might have been the most important external factors affecting fertility.

Temperature is known to affect the activity of birds. Exposure to low temperatures in breeding pens that are poorly insulated is believed to reduce the activity and normal physiological functions of birds. Frostbitten combs and wattles make males so uncomfortable that they mate infrequently. Females, too, are likely to spend more time on the roosts. The data bearing on temperature and fertility are summarized in Table 1 and illustrated graphically in Chart 1 by combining the late- and early-hatched groups.

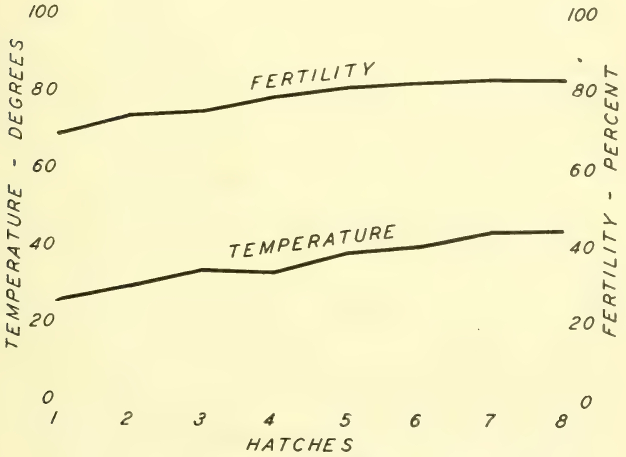

Chart 1. Relation Between Temperature and Fertility.

Table 1 shows the number of females bred from, the number of eggs, the mean outside temperature during the time the eggs were laid, and the mean fertility as calculated by averaging the fertility records of the individual females for each of the eight hatches.

For the ten-year period from 1922 to 1932 the average temperature increased about 17 degrees from February 22 to March 5. The average outside temperature during the time the first two settings of eggs were laid was below freezing. Following this period the temperature rose rather consistently to an average of 45.75° at the time the eggs for the last two settings were laid. It seems probable that these records over a ten-year period are fairly representative of what may be expected in this locality.

TABLE 1.—OUTSIDE TEMPERATURE AND FERTILITY*

Late Group, Hatched March 25 to May 15 1922–1932					Early Group, Hatched March 4 to April 27 1933–1936				
Hatch No.	Number of Birds	Number of Eggs	Mean Temperature °F.	Mean Fertility Percent	Hatch No.	Number of Birds	Number of Eggs	Mean Temperature °F.	Mean Fertility Percent
					1	492	2759	15.86	54.47
					2	511	2094	20.75	61.02
					3	552	2339	27.34	64.58
1	1441	8378	28.80	73.09	4	609	2665	23.39	66.70
2	1454	6285	31.72	77.49	5	656	2883	33.09	70.24
3	1531	6565	35.81	78.12	6	670	3096	34.00	74.93
4	1511	6727	36.51	82.53	7	643	3086	37.41	78.52
5	1438	6360	39.01	84.15	8	616	3006	38.95	76.96
6	1438	6248	41.46	84.47					
7	1336	5711	45.76	84.21					
8	1250	5444	45.75	84.81					

*Includes all experiments.

A study of mean fertility for successive hatches in a different group of females in successive years showed considerable parallelism between outside temperature and fertility. When the mean outside temperature averaged below 36°, fertility was significantly lower, as shown by the first three hatches. When the outside temperature rose to 40° or 45°, the maximum fertility was attained. Within the temperature ranges studied, there appears to be a relation between outside temperature and fertility.

Considering the group where hatching took place three weeks earlier, it will be noted that the mean outside temperature was well below freezing at the time eggs were laid for the first four hatches. As the temperature rose during the collection of eggs for the first four hatches, there was a consistent increase in mean fertility. As the temperature increased during the collection of eggs for the last four hatches, fertility still increased, attaining a maximum at 37°.

Hatch 1 of the late group was made from eggs collected on the same dates as hatch 4 in the early group. The mean temperature was higher during the ten years that data were collected for the late group than during the four years that data were collected for the early group, but in both cases the temperature averaged below freezing. Mean fertility was also significantly higher for the late group. Late hatch 2 and early hatch 5 are not consistent in that the former showed a significantly greater fertility than the latter, when the mean temperatures were about the same. There was a slight superiority in late hatch 3 over early hatch 6, and the temperature was also slightly higher when the eggs for hatch 3 were laid. There was slightly higher fertility in late hatch 4 than in early hatch 7, although the temperature differences were negligible. In late hatch 5 and early hatch 8, from eggs produced under the same temperature conditions, hatch 5 had superior fertility.

The data in Table 1 furnish further information on the relation between outside temperature and fertility. The mean fertility for the eight hatches was 81.11 percent in the late group, while in the early group it was 68.43 percent. The mean temperature was 38.10° during the time the eggs were laid for the late group and 28.85° during the time the eggs were laid for the early group. Since the character of the stock was not changed and the methods of feeding and management were kept constant, it is very probable that lower temperatures were in large measure responsible for the lower fertility of the early group.

2. Relation Between Age of Breeding Stock and Fertility

Curtis and Lambert (1929) studied the effect of age of birds on fertility. Their data showed that cockerels mated to hens gave a greater duration of fertility from a single mating as well as a larger number of fertile eggs than did cockerels mated to pullets. Cocks mated to hens gave a slightly greater duration of fertility but slightly fewer fertile eggs than did cockerels mated to pullets. Cocks mated to hens gave a higher fertility record than cockerels mated to pullets but the number of fertile eggs from the older parents was smaller.

Jull (1935) reported on fertility in White Leghorns, Rhode Island Reds, and Barred Plymouth Rocks from mating cockerels to pullets, yearlings, and two-year-olds. In the Leghorns fertility declined slightly with an increase in the age of the females. With Rhode Island Reds fertility was essentially identical in pullets and in yearlings, with a slight decline in the two-year-olds. In the Barred Plymouth Rocks highest fertility appeared in the two-year-olds, and pullets showed the lowest fertility. In crossbreeds fertility was greater in the pullets than in the yearlings.

A study has been made on the effect of age of parents on fertility for the period from 1922 to 1936. In these studies all inbred and outbred matings have been eliminated. The data are divided into the late- and early-hatched groups. The data for 1926 are omitted as indicated in Section 1.

The relation of age of male to fertility may be considered first. It will be noted (Table 2) that the mean fertility from cockerels in the late-hatched group was 82.94 percent and in the early-hatched group, 82.73 percent. Yearling males gave a mean fertility of 71.88 and 58.29 percent respectively in the two groups. Two-year-old males had a mean fertility of 68.94 and 30.84 percent. Males three years old or over showed a mean fertility of 24.06 and 30.40 percent. An ideal set-up for testing the effect of age, either of males or females, on fertility would include a large group of males mated to the same group of females, beginning when the birds were twelve months old and continuing until they were four or five years old. The number of birds in these tests, however, appears to be adequate to indicate a definite decline in fertility of males with increasing age. Jull (1935) found that White Leghorn and Rhode Island Red males had higher fertility as cockerels than as yearlings.

Another very significant fact indicated by Table 2 is that cockerels gave the same fertility in the early-hatched group as in the late-hatched group, while yearling and older males showed a very significant lowering of fertility by earlier hatching. It is evident, therefore, that the cockerels were in a more active state of sexual function than older males, even under rather severe weather conditions.

Fertility in females of different ages is recorded in Table 2 under mean of classes. In the late-hatched group, yearling females had a significantly higher fertility than pullets when mated to males of any age. These data are not in agreement with those of Jull (1935), but Jull does not report hatching dates. In the early-hatched group, however, pullets showed a significantly higher fertility than yearlings; but when the eight yearlings that were mated to very old males are omitted, the fertility records of pullets and yearlings do not differ significantly. The group of 52 two-year-old hens appears to have been fully equal to the younger birds in fertility, but the number is too small to carry any particular significance. These data suggest that the fertility of females of all ages is less affected by weather conditions than is the fertility in males.

The effects on fertility of mating birds of different ages should also be considered. In both groups cockerels gave the highest fertility when mated to

TABLE 2.—AGE OF BREEDING STOCK AND FERTILITY

Age of Females	Age of Males												Mean of Male Classes
	Cockerels			Yearlings			2-Year-Olds			3-Year-Olds or Older			
	Number of Females	Number of Eggs Set	Mean Fertility	Number of Females	Number of Eggs Set	Mean Fertility	Number of Females	Number of Eggs Set	Mean Fertility	Number of Females	Number of Eggs Set	Mean Fertility	
					Late Group, 10 years								
Pullets	423	14,836	85.51	146	4,655	72.09	53	1,715	73.99	10	240	23.75	63.84
Yearlings	187	5,859	91.50	198	6,335	76.39	36	1,100	76.91	19	362	28.73	68.38
2-year-olds	40	1,016	75.10	58	1,696	63.86	21	638	57.99	10	137	19.71	54.17
3-year-olds and older	23	575	79.65	9	274	75.18	11	320	66.88	—	—	—	73.90
Mean of classes			82.94			71.88			68.94			24.06	
					Early Group, 4 years								
Pullets	223	7,635	77.56	66	2,007	66.97	46	1,444	32.48	—	—	—	59.00
Yearlings	54	1,470	86.33	84	2,654	67.29	17	591	18.78	8	138	18.84	47.81
2-year-olds	20	492	86.38	8	224	76.34	20	480	35.83	4	112	41.96	60.13
3-year-olds and older	5	62	80.65	5	133	22.56	4	80	36.25	—	—	—	46.49
Mean of classes			82.73			58.29			30.84			30.40	

yearlings. Yearling males gave the highest fertility from yearling hens in the later hatches, but the number of tests is too small for significance in the earlier hatches. Two-year-old males gave the highest fertility when mated to females of their own age. The very old males appeared to give highest fertility when mated to yearlings. Females two years old or over gave the highest fertility record when mated to cockerels. Since the data indicate that fertility declines consistently with age in males and to a lesser degree in females, a mating between young birds and old birds might raise the fertility. When, however, the physical condition of the birds is superior and environmental conditions are right, the mating of aged birds will generally give satisfactory fertility.

3. Relation Between Sex and Fertility

It is desirable to know whether a difference exists between the sexes with respect to fertility. Crew (1926) pointed out selective fertilization on the basis of sperm competition when two different males were used. Dunn (1927) presented data indicating selective fertilization on the basis of relationship of the birds mated. He secured higher fertility from related matings within a breed than from breed crosses. Warren and Kilpatrick (1929) found some evidence of selective matings and very conclusive evidence of sperm competition.

Selective mating occurs rather frequently in most poultry flocks. In almost any series of mating pens females will appear that never lay fertile eggs. Such infertility may be caused by selective mating either on the part of the female or on the part of the male or possibly by incompatibility between sperm and ova. The data in Table 2 show that increased age has a greater effect upon the fertility of males than upon the fertility of females.

The fertility records of the individual males were tabulated by years. The fertility of individual males represents an average of the fertility of all of his mates. These records did not show a normal frequency distribution at any time, but for the most part approached a bimodal distribution with a rather conspicuous separation at the 60 percent fertility class. This bimodal distribution suggested the possibility of two genetic phenotypes for fertility. The minor irregularities of the curves pointed to other modifiers, some of which may have been genetic. The fact should be noted in this connection that males and females have never been selected directly for high fertility. There has been indirect selection in that birds have been chosen from large families and older breeding males, and females were not used unless they had shown the ability to produce abundant offspring.

The mean percentage of fertile matings for the males used throughout the fourteen years is recorded in Table 3 to show how fertility behaved from the standpoint of the males. The percentage of males with a fertility record of 61 percent or higher is also recorded. These data do not point to any significant change in the appearance of fertile matings in the first ten-year period. In the earlier hatching period of the last four years the males had a somewhat lower rating, but within this period there was relatively little change in the mean percentage of successful matings.

The mean percentage of males with a fertility record exceeding 60 percent fluctuated widely throughout the period but showed no specific change in the ten-year period. In the early-hatched group of the last four years, the percentage of superior males fell to a low level and remained there. In general, the percentage of successful matings and the percentage of superior males changed little during the period studied.

Table 3.—The Behavior of Fertility from the Standpoint of the Males (Omitting Outbreds and Inbreds)

Year	Number of Males	Percentage of Fertile Matings	Percentage of Males with 61 percent Fertility or Higher
	Late Group		
1922	17	98.85	94.12
1923	22	86.85	59.09
1924	27	92.14	70.37
1925	27	89.92	77.78
1927	23	91.35	82.61
1928	29	93.46	82.76
1929	24	88.10	75.00
1930	21	94.07	80.95
1931	19	94.62	94.74
1932	19	93.33	89.47
	Early Group		
1933	20	90.80	75.00
1934	20	84.62	60.00
1935	21	84.18	71.43
1936	16	82.84	68.75
Total and means	305	90.37	77.29

Results from Changing Males

When breeding females continue to lay infertile eggs during the breeding season, a common practice is to mate to a different male. The prevalence of such females in the flock and the effectiveness of such a procedure has been studied. The data are presented in Table 4.

Table 4.—Change of Male as Affecting Fertility

Classes of Females	Late Group		Early Group	
	Number	Percent	Number	Percent
Total females	1237		538	
Females mated to one male and infertile	40	3.23	57	10.59
Male Changed:				
Females infertile, then fertile	50	4.04	21	3.90
Females infertile, then infertile	4	.32	2	.37
Females fertile, then infertile	2	.16	0	0.00
Females fertile, then fertile	80	6.47	34	6.32

In the late-hatched group 1,237 females were included. Of this number 3.23 percent remained infertile throughout the breeding season when mated to one male. There were 54 females that began the breeding season laying infertile eggs and that were later mated to a different male. Almost 93 percent of these females began to produce fertile eggs after the introduction of the second male. Even though temperature conditions were more conducive to fertility at the time the second male was used, the data suggest that in the majority of cases the male was responsible for infertility and that a change of males was very effective. Two females that were fertile became infertile with a change of males; and 80 females were fertile with both males. A change of males was not made because of infertility in these cases.

In the early-hatched group, the number of infertile matings when the male was not changed rose to 10.59 percent. There were 23 females that began the breeding season laying infertile eggs. A change of males was followed by 91 percent laying fertile eggs. Here again is evidence that the male was very likely responsible for the infertility. In this group 6.32 per cent of the females were fertile with both males.

The combined data show that out of 1,775 matings, 174 females (9.8 percent) started the breeding season laying infertile eggs. An attempt was made to overcome this infertility in 77 cases by a change of male, and in 71 matings of the 77 a change in male was followed by fertility.

Constancy of Fertility in Females

Jull (1935) reported that fertility in Leghorn, Rhode Island Red, and Crossbred females was highest in the pullet year and that it declined in the yearling and in the two-year-old. His birds were mated to cockerels in all cases. In our data females that were bred from for more than one year are considered. The age of males used ranged from cockerels to three-year-olds. The data are summarized in Table 5.

TABLE 5.—FERTILITY OF FEMALES USED FOR MORE THAN ONE YEAR

Classes of Females	Began as Pullets		Began as Yearlings	
	Number of Females	Percentage of Failures	Number of Females	Percentage of Failures
Used for two years:				
First year	129	3.10	105	0.00
Second year	129	6.20	105	8.57
Used for three years:				
First year	24	0.00	22	0.00
Second year	24	0.00	22	0.00
Third year	24	4.17	22	0.00
Used for four years:				
First year	4	0.00	6	0.00
Second year	4	0.00	6	0.00
Third year	4	0.00	6	0.00
Fourth year	4	0.00	6	16.67

A group of 129 females showing 3.10 percent of infertile matings as pullets showed 6.20 percent of infertile matings as yearlings. There were 24 individuals tested for three years with no unsuccessful matings the first two years and 4.17 percent failures in the third year. Four females were carried through four seasons without any infertile matings.

A group of 105 birds was tested first as yearlings and carried through two breeding seasons. There were no infertile matings as yearlings and 8.57 failures as two-year-olds. A group of 22 females began as yearlings and carried through three seasons with no infertile matings. Six birds had no infertile matings through three seasons, but as four-year-olds showed 16.67 percent failures.

These data in general agree with the observations of Jull (1935). As a rule, fertility of females appears to decline with age. There are many exceptions to this rule, however, and the data suggest that age in females is less important than in males. It seems probable, also, that the male is more important than the female from the standpoint of fertility.

4. Relation Between Winter Egg Production and Fertility

The number of eggs laid from the first pullet egg up to March 1 varies widely in a flock bred for high production. This winter egg record depends upon a number of factors such as hatching date, age at first egg, intensity, and winter pause, as well as upon many environmental influences. For the period from 1922 to 1936 the mean yearly egg production ranged from 76 to 104 eggs and the individual range was from 1 to 165. It is desirable to know whether there is any relation between winter egg production and the fertility of eggs laid from February 1 to April 25 of the pullet year. The mean fertility of pullets in the different winter egg production classes is recorded in Table 6.

TABLE 6.—MEAN FERTILITY OF DIFFERENT EGG PRODUCTION CLASSES INCLUDING ZERO FERTILITY

Winter Egg Production	Late Group		Early Group	
	Number of Birds	Mean Fertility	Number of Birds	Mean Fertility
1-15	1	85.50	—	—
16-30	8	93.00	1	65.50
31-45	24	77.35	5	75.50
46-60	67	75.90	24	78.60
61-75	153	71.85	62	72.64
76-90	198	73.92	76	62.25
91-105	132	78.61	89	71.11
106-120	75	80.54	65	62.71
121-135	37	75.89	25	70.22
136-150	7	82.64	11	44.41
151-165	—	—	4	42.75
Totals	702		362	

A study of the 702 pullets in the late-hatched group indicates no relation between winter egg production and fertility. In the early-hatched group there was a slight tendency for the very heavy winter layers to exhibit lower fertility than the average or below-average producers. The data are inconclusive on this point, and further information is desirable.

5. Relation Between Number of Mates to the Male and Fertility

The range in number of mates to each male was rather limited in these data. The number of females in each mating pen varied from 1 to 14, with 8 to 10 being the most common number. It is desirable to see whether, within these limits, there was any significant relation between the number of females mated to a male and fertility. The percentage of unsuccessful matings was considered to be the best measure of relationship.

TABLE 7.—PERCENTAGE OF UNSUCCESSFUL MATINGS FROM MALES MATED TO DIFFERENT NUMBERS OF FEMALES

Number of Mates	Late Group		Early Group	
	Number of Males	Mean Percent Failures	Number of Males	Mean Percent Failures
1	2	0	0	
2	5	20.0	0	
3	7	28.6	0	
4	6	12.5	0	
5	10	3.3	1	0
6	16	3.3	0	
7	25	4.4	11	4.3
8	44	5.0	14	10.1
9	23	12.9	15	9.9
10	37	4.3	18	31.1
11	11	14.1	4	3.1
12	21	6.2	13	12.2
13	13	1.5	1	0
14	7	27.4	0	

The data in Table 7 show that a variation from 1 to 14 in the number of females mated to a male had no effect upon fertility in either the late- or the early-hatched groups. In other words, the range in number of females used was inadequate to test the fertilizing power of the males. The wide fluctuations in percentage of unsuccessful matings are apparently due both to selective matings and to germ cell incompatibility. No data are available on the relative importance of these two factors.

6. Progress in Improving Fertility

Throughout the period covered by these studies, selective breeding for high hatchability and for large families was constantly practiced. If fertility were an inherited trait it is conceivable that fertility would have shown an increase as the work progressed. In Table 8 the percentage of unsuccessful matings is recorded by years for females of different ages, together with the mean fertility of all birds except inbreds and outbreds each year.

TABLE 8.—PROGRESS IN IMPROVING FERTILITY
(Omitting Outbreds and Inbreds)

Year	Pullets		Yearlings		Females 2 Years Old		Females over 2 Years Old		Mean Fertility
	Number of Birds	Unsuccessful Matings Percent	Number of Birds	Unsuccessful Matings Percent	Number of Birds	Unsuccessful Matings Percent	Number of Birds	Unsuccessful Matings Percent	
					Late Group				
1922	41	2.44	45	0.00					73.41
1923	56	8.93	56	14.28	25	20.00			68.22
1924	44	4.55	71	5.63	19	26.32	6	0.00	78.89
1925	57	17.54	50	6.00	18	0.00	4	0.00	67.69
1927	88	7.95	97	9.28	18	16.67	6	0.00	74.77
1928	139	8.63	50	0.00	18	11.11	7	0.00	74.74
1929	117	10.26	37	16.22	7	28.57	7	0.00	76.39
1930	52	5.77	49	6.12	11	0.00	6	0.00	72.49
1931	49	0.00	19	0.00	19	26.32	6	0.00	88.15
1932	59	3.39	12	16.67	11	0.00	8	25.00	84.97
					Early Group				
1933	95	5.26	52	9.62	8	25.00	8	37.50	75.21
1934	95	2.11	27	0.00	19	5.26	2	50.00	56.81
1935	96	2.19	51	7.84	9	0.00	2	0.00	65.76
1936	76	10.53	40	27.50	16	25.00	2	0.00	72.42
									73.57

The data show that fertility, as measured by the percentage of infertile matings, did not change throughout the fifteen-year period. In other words, there was no apparent tendency for the number of unsuccessful matings to decrease, but there was a wide fluctuation from year to year. The last column of the table gives the mean of individual fertility records by years and shows that there was no progress in raising the mean level. These data lend no support to Jull's (1935) assumption that fertility is an inherited trait.

7. Relation Between Inbreeding and Outbreeding and Fertility

Four types of matings have been considered in the inbred series: full brother and sister, half-brother and sister, sire and daughter, and son and mother. Experimental evidence on the effects of inbreeding is not entirely conclusive at present.

Outbreeding, using outside stock within the breed, is believed by many to be effective in increasing fertility. In these studies outside stock was used from five different sources. Stock W was represented by 2 males, stock D by 14 males, stock S by 4 males, and stocks T and P by males from hatching eggs obtained from the two sources. Check matings include all matings in the flock not included under inbreds or outbreds.

Mean fertility may be taken as the average of the individual mating records of each male when mated to one or more females. Fertility may also be measured by the percentage of unsuccessful matings. In Table 9, the data for inbred, outbred, and check matings are recorded in the two categories.

TABLE 9.—FERTILITY OF INBREDS, OUTBREDS, AND CHECKS

	Number of Males	Mean Fertility	Percentage Infertile Matings
INBREEDING			
1922-1932			
Brother x Sister	32	80.96	3.85
Half-brother x Sister	60	78.50	2.92
Sire x Daughter	13	50.26	16.00
Son x Mother	11	74.62	0.00
1933-1936			
Brother x Sister	3	67.33	0.00
Half-brother x Sister	9	71.49	0.00
Sire x Daughter	2	86.82	0.00
Son x Mother	—	—	—
Combining all years			
Brother x Sister	35	79.79	3.45
Half-brother x Sister	69	77.58	2.52
Sire x Daughter	15	55.13	14.04
Son x Mother	11	74.62	0.00
CHECKS	305	73.57	9.63
	Outside Males		
OUTBREEDING			
W	2	91.64	0.00
D	14	73.25	4.35
S	4	97.20	0.00
T-1922-1932	10	94.80	0.00
1933-1936	7	75.42	3.45
Total	17	86.82	1.61
P	6	77.26	5.56

In the inbred group mean fertility was slightly higher from full brother–sister matings. Son–mother matings gave a slightly lower mean value than half-brother–sister matings. Matings of sires to their daughters gave a very low fertility record. On the basis of percentage of unsuccessful matings, son–mother was the most favorable with all matings successful, while sires mated to daughters gave 14 percent of unsuccessful matings. On the basis of mean fertility as well as of unsuccessful matings, all types of inbred matings except sire on daughter were superior to the check group.

In general, outbreeding raised the mean fertility level above that of inbreds or checks. The D males, the T stock used in the last four years, and the P stock crosses did not raise the mean fertility significantly above that of the checks. On the basis of percentage of unsuccessful matings, all outside stock proved superior to the checks but not superior to three of the four types of inbred matings.

Comparing mean fertility with the percentage of unsuccessful matings gives some interesting information. The percentage of unsuccessful matings indicates the relative number of incompatible matings due either to the failure of the birds to mate or to the incompatibility of sperm and ova. Mean fertility is governed largely by the number of such unsuccessful matings. Son–mother matings were very successful as measured by limited data. Half-brother–sister matings were also generally successful, but sire–daughter matings gave 14 percent of failures. In the outbred males, W and S were entirely successful. The T stock gave complete compatibility for the first ten years. The matings from 1933 to 1936, made three weeks earlier in the season, gave the same percentage of failures as did all brother–sister matings. Outside stock P gave fewer failures than the check group, but was inferior to all other outside stock and to most inbred matings.

8. Correlation Between Mothers and Daughters in Fertility

Considering the character of the data available, the best measure of the possible inherited nature of fertility is the coefficient of correlation for fertility of mothers and daughters. Omitting inbreds and outbreds, data were available on 466 mothers producing 1,452 daughters with fertility records. In the tabulation each mother was paired against each of her daughters. Daughters with zero fertility were included in the tabulation. The constants derived were as follows:

Number of mothers	466
Number of daughters	1452
Mean fertility of mothers, percent	89.31
Mothers' fertility standard deviation	±12.91
Mean fertility of daughters, percent	71.83
Daughters' fertility standard deviation	±33.20
Coefficient of correlation	.0209 ± .0177

Mean fertility of mothers was significantly higher than that of their daughters, partly because 157 daughters had zero fertility. When these 157 daughters are omitted, the mean fertility of the daughters was 80.54 percent, still significantly below that of the mothers. Standard deviation in fertility was much greater in daughters, whether the zero class was included or not. This standard deviation is exaggerated in the daughters because there were more than three times as many daughters as mothers.

The coefficient of correlation in fertility between mothers and daughters is so near zero as to be insignificant. Regression was found to be linear. The insignificant value of the coefficient of correlation indicates that factors other than inheritance control fertility and that selective breeding to improve fertility would, therefore, be ineffective.

Summary

A study was made of 2,101 Rhode Island Red females and 305 males used in pedigree matings from 1922 to 1936 to secure information on various factors that might affect fertility and to discover whether fertility is an inherited trait. From the data available, several conclusions may be drawn:

1. Outside temperature during the period that hatching eggs are laid had a specific effect on fertility. When the average temperature was below 32°, average fertility ranged between 54 and 77 percent. When the temperature rose to above

freezing, fertility ranged from 70 to 85 percent. With weekly hatches over an eleven-week period, fertility rose consistently until the outside temperature was about 37°.

2. Males had their maximum fertility as cockerels and showed a marked decline in fertility each succeeding year. Females had their maximum fertility as yearlings and exhibited a less marked decline in fertility in succeeding years than did the males.

3. The percentage of fertile mates for the males used each year remained essentially unchanged through fifteen years. This fact tends to discredit the idea that fertility is governed by inheritance, because indirect selection for high fertility was constantly practiced. The percentage of males having a fertility record of 61 percent or more remained unchanged throughout the experimental period.

4. Males appeared to be responsible for infertile matings in most cases, because a change of males resulted in 93 percent of the infertile matings becoming fertile.

5. Females did not show a constant fertility from year to year but were likely to exhibit declining fertility after the yearling age.

6. The number of eggs laid by pullets up to March 1 had no significant effect on their fertility record.

7. A range from 1 to 14 in the number of females mated to each male had no effect upon the fertility record of the males.

8. The percentage of infertile matings fluctuated considerably during the period but showed no definite trend.

9. Mean fertility, obtained by taking the average of the individual female records, had no definite trend in fifteen years.

10. Fertility was highest when outside males were mated to Station females. From inbred matings fertility was higher than from check matings, except when sires were mated to their daughters. The percentage of unsuccessful matings was high with sire-daughter matings but lower in other inbred matings than in the checks. Outside stock from three different sources, when mated to Station stock, gave no infertile matings, but stock from two other outside sources gave as many infertile matings as did most inbred matings.

11. There was no correlation between fertility of mothers and daughters, suggesting that fertility does not depend on inheritance.

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Farm Storages for New England Apples

By C. I. Gunness, W. R. Cole, and O. C. Roberts

Proper storage of apples on the farm makes possible the delivery of good fruit in prime condition to the consumer. This bulletin attempts to aid the producer in that accomplishment.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

FARM STORAGES FOR NEW ENGLAND APPLES

By C. I. Gunness, Professor of Engineering; W. R. Cole, Extension Specialist
in Horticultural Manufactures; and O. C. Roberts,
Assistant Professor of Pomology

THE FUNCTION OF STORAGE

Storage is one of the most important factors in the orderly distribution of the apple crop. If no apples were stored, all would go to market at harvest time and none would bring satisfactory prices. Stored apples may be marketed in such a way as to stabilize supply and prices, and usually sell at prices higher than those which prevail at harvest time or soon after.

Consumers are now demanding high quality apples, such as the McIntosh, over a period of five months or more. Storages are needed in order to hold these apples in a sound condition from the time of harvest until they are offered for sale.

What Storage Does to an Apple

An apple grows as a part of a living organism — the tree. Before harvest it continues to receive materials from the tree and the net result of these life processes is growth and increased weight. After removal from the tree, life must be sustained on food stored in the apple. Life processes are destructive, and when they have run their course, the apple dies. This natural breakdown of the apple is marked by a gradual darkening of the flesh beginning at the core, and may occur without rotting. Frequently, decay organisms attack the apple and it rots before its food reserves are completely exhausted.

The changes that take place within the apple are the result of chemical reactions. The important constituents affecting the quality of an apple are starch, sugars, acids, tannins, pectins, and esters which are compounds responsible for the characteristic odor and flavor of a particular variety. Quality in an apple depends chiefly upon the proportions of sugars and acids. Prior to harvest, an apple contains a relatively large quantity of starches. In the process of ripening, the starches change to sugars and the acids and tannins diminish, thus making the apple more agreeable to eat. Changes in the character of the pectins are believed to be responsible for the "mealy" or granular condition of the flesh as apples become overripe. Chemical changes within the apple are accompanied by the utilization of oxygen and the evolution of carbon dioxide. This process is known as respiration and is a measure of the speed of ripening. These chemical changes are hastened by heat and retarded by cold. If left in the orchard, an apple may reach its maximum quality for human consumption in early autumn. If exposed to low temperatures before that maximum is reached, development may be retarded and a condition of prime eating quality reached in February or March instead of September or October. This is the function of storage. No method has yet been discovered by which life processes in an apple may be stopped and the apple held indefinitely at one stage of development without killing it. The progression must go on, but efficient storage slows it down to a marked degree.

HANDLING THE CROP

Ways of Handling Apples from Orchard to Market

After a crop of clean, well-matured fruit is grown and harvested, the next problem is to handle the apples in such a way as to insure the maximum net returns. Conditions vary to such an extent that methods employed in one orchard may not be suitable for another. Unless apples are to be sold immediately after harvest they should be placed in a suitable storage. Early and mid-season varieties, such as Wealthy, Duchess, and Gravenstein, should be placed in cold storage if they are to be held for a month or more before going to market. Late varieties such as Baldwin, Northern Spy, and Wagener may be held quite satisfactorily until March 1 in a well-managed, air-cooled storage. Some growers occasionally have reasonably good success in storing McIntosh in air-cooled storage for short periods, although in some seasons sufficiently low temperatures cannot be maintained in this type of storage at harvest time to retard adequately the ripening process.

Some of the more common methods of handling the apple crop are as follows:

1. *Store, grade, pack, and sell.*

In this case the fruit goes directly into storage as it is picked. Advantages of this system are:

(a) It reduces the pressure of work at harvest time.
(b) The packing may be done by a small, well-trained crew after the rush of the harvesting season is over.
(c) The apples are packed as they are sold, thereby offering to the trade a fresh pack of sound fruit.

An objection to this system is that valuable storage space is wasted on culls and low-grade fruits that under other systems would be eliminated and not stored. This objection may be overcome in part if the culls are removed as the apples are placed in the field boxes.

2. *Grade, pack, store, and sell.*

With this method the apples are graded and packed for market, then placed in storage until sold. As a result, only the better grades of fruit are stored while the poorer grades are disposed of immediately.

The chief objections to this method are:

(a) A larger crew is required at harvest time.
(b) Fruit that has been held in cold storage for several months frequently needs repacking.

3. *Grade and pack in orchard and sell immediately.*

This method requires a minimum amount of equipment, gives the grower an immediate cash return for his fruit, and relieves him from further worry concerning it. However, apples handled in this way usually arrive on the market in competition with abundant supplies of cheap fruit and consequently have to be sold at a relatively low price as compared with similar apples that are held in storage until the market has become more stable.

4. *Grade, store, pack, and sell.*

With this method the apples are sorted and the better grades stored according to grade and size and later packed as they are sold. While this system necessitates extra handling, it facilitates the filling of an order for a specific grade and size of fruit and insures its arrival on the market in a more attractive condition than when it is packed and then stored.

Time of Harvesting in Relation to Storage

Success in the storage of apples depends to a large extent upon the stage of maturity of the fruit when it goes into storage. For best results apples should be mature but not overripe. If immature, they lack good quality, are more susceptible to scald, and tend to wither more readily than when fully mature. If overripe, they break down more quickly, and thus the length of time that they may be kept in storage is shortened.

Methods that are commonly used for determining the proper time for harvesting are:

1. *Change in ground color.*

The term "ground color" refers to the green portions of the skin. As apples approach maturity the ground color changes from a deep green to greenish yellow. This is one of the most valuable indicators of maturity.

2. *The ease with which the fruit separates from the spur.*

This condition is most commonly noted by the amount of dropping, and is usually a reliable indicator. It is not entirely dependable, as some varieties such as Cortland will hang to the tree after the optimum picking condition has passed while other varieties may "drop" prematurely. The time and amount of dropping may also be affected by weather conditions prior to the harvesting season. However, as a rule, when apples begin to drop, they may be considered as having reached the optimum picking condition. With varieties which drop freely, such as the McIntosh, it is often necessary to start picking before any marked dropping occurs in order to finish harvesting the crop before too many of the apples are on the ground.

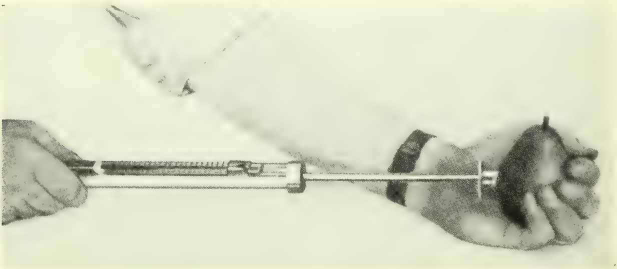


Figure 1. Pressure Tester.
Courtesy of D. Ballauf Mfg. Co., Washington, D. C.

3. *Firmness of the flesh.*

Experienced growers usually determine this by pressing the fruit with the thumb. A more accurate measure of firmness of the flesh may be made by a pressure tester. Apples that are to be held for several months should not be left on the tree beyond a certain stage of development, which varies with different varieties. Experimental evidence indicates that the pressures at which some of the common varieties should be picked are approximately as follows: McIntosh 14 pounds, Baldwin 19 pounds, Delicious 18 pounds. The pressure tester is used rather extensively in the West to determine the proper stage of maturity for harvesting fruit, especially pears. As growing conditions vary to a much greater extent in the East, the pressure tester cannot be used with the same degree of accuracy. This instrument is particularly useful in the case of varieties that tend to hang on the trees beyond the optimum picking date. It is especially valuable as a means of measuring the condition of apples in storage.

4. *Color of seeds.*

Seed color is frequently mentioned as an indicator of the condition of the fruit, but since the seeds in late varieties of apples commonly grown in New England turn brown from one to three weeks before the fruit reaches maturity, the color of the seeds is an unreliable indicator of the optimum picking date.

5. *Red color.*

Highly colored apples usually bring a premium on the market. Therefore, it is a common practice among fruit growers to leave apples on the trees as long as possible in order to obtain the maximum amount of color. However, in some cases, extra color is obtained at the expense of the keeping quality of the fruit. Apples that are shaded often become overmature or drop before developing the desired color. Therefore, the amount of red color in itself cannot be depended upon as an indicator of the condition of the fruit.

In brief, the principal observations that should be made to determine the proper time for picking apples are:

1. When the "ground color" changes from deep green to yellowish green.
2. When the stems of the apples separate easily from the spurs or when apples begin to drop.
3. When the pressure test, as determined by hand pressure or by pressure tester, indicates that the apples have started to soften.

Time of Harvesting McIntosh

Since the McIntosh variety is of particular importance in New England, it deserves special consideration as to the relationship between the time of harvest and keeping quality.

Because of wide variations in soil type and altitude of McIntosh orchards in New England, together with differences in climatic conditions and cultural practices, it is difficult to specify a particular date at which the McIntosh harvest should begin. However, the practice of twenty-two leading New England fruit growers over a period of five years, as reported in a recent survey, indicates that the majority started picking between the 8th and 12th of September. The duration of the harvesting period varied from five to twenty-seven days, but the majority of growers harvested the crop in from ten to twelve days.

A few growers in Connecticut, Massachusetts, and New Hampshire started picking as early as September 1, while others in these same states did not start until as late as September 20. Of the two reporting from Vermont, one grower started picking as early as September 4 in 1931, and the other delayed until September 16 in 1935. Although both orchards are located in the southern part of Vermont, one grower started picking five days earlier than the other, on an average.

These reports indicate either that there is a wide difference in growing conditions between and within the several states or that some crops were not picked at the optimum time, particularly if they were to be stored. It seems reasonable that the latter is the more probable explanation, particularly in large orchards where, owing to labor conditions, the harvest must be started early in order to avoid excessive drop.

Limits of Storage for McIntosh

There is a tendency on the part of many growers to hold McIntosh until too late in the season for the ultimate good of the variety. The popularity of McIntosh is due to its exceptional quality when in prime eating condition. The continued popularity of this variety depends upon its distribution to the consumer before it has lost its characteristic flavor. This opinion is supported by replies from twenty-two prominent New England growers, 60 percent of whom indicated that McIntosh should be sold before March 1. It therefore appears that a majority of the better growers appreciate the fact that by the end of February McIntosh apples, even when held in cold storage, have lost their characteristic quality and when sold after that date are not likely to add to the popularity of the variety.

The Grade of Fruit to Store

It is desirable that fruit which is to be stored for three months or more should comply with the standards of U. S. Commercial grade or better. It is economically unsound to store apples that are seriously defective because of insects or diseases, or that have been carelessly handled at harvest time. Apples with an unbroken skin are not likely to rot in storage, as bruises and skin punctures are the usual points of origin of decay. This is because fungus spores which cause decay enter the apple through breaks in the skin. More damage is caused by the fingernails of the pickers and sorters than is commonly appreciated. Decay frequently starts where the skin of the apple is ruptured from stem punctures.

Storage Packages

Ninety percent of the apples held in New England storages are stored in approved Eastern apple boxes. The remainder are stored in standard produce boxes, Western style boxes, cardboard cartons, and baskets. Cartons are used for packed fruit only, while the others are suitable for storing either loose or packed fruit. Baskets are the least desirable as they do not stack as neatly as boxes, provide less protection for the fruit, and are wasteful of storage space.

CONDITIONS ESSENTIAL FOR SATISFACTORY STORAGE

In order to keep apples most satisfactorily, it is essential that the proper conditions of temperature, humidity, and ventilation be maintained within the storage room.

Temperature

Since the changes in an apple are chemical in nature, the speed of these reactions is affected by the temperature at which the apple is held. At a temperature of 40° F. ripening proceeds about twice as rapidly as at 32° F. Consequently at the higher temperature, apples mature more rapidly and reach the final stages more quickly than at lower temperatures. The function of storage is to hold apples at a comparatively low temperature in order to retard the ripening processes. The efficiency of a storage is measured by the degree to which it delays ripening without otherwise injuring the fruit.

The temperature recognized as the most desirable for storage of apples grown in New England is 32° F. Apples freeze at a temperature of 28°-29° F.; therefore a temperature of 32° F. is adequate to retard the ripening processes within practical limits and yet allow a margin of safety if the storage temperature should drop a few degrees. Furthermore, cold pockets may develop in some remote parts of the storage room where the temperature may be lower than that indicated by the thermometer.

Effect of storing McIntosh apples at modified temperatures

McIntosh apples that are to be held in cold storage are commonly picked while slightly immature and are consequently "green" in flavor. When these apples are stored immediately at 32° F., development of the normal flavor is checked and on removal from storage they lack that high quality which is characteristic of a well-ripened McIntosh.

Recent experiments at the Massachusetts Station indicate that, when this variety is to be held in storage not later than January first, a higher initial storage temperature will result in better eating quality than when apples are held at 32° F. continuously. In these experiments the storage was held at 45° F. during the ten-day harvesting period and for five days thereafter. At the end of this time the temperature was reduced about two degrees each day until 32° F. was reached. Apples stored according to this system ripened more rapidly than those held at 32° F. continuously, as shown by the graph in Figure 2. Consequently, this method of storage is not recommended for apples that are to be held after January 1, but is recommended for McIntosh apples that are to be sold before that date, provided maximum quality is desired.

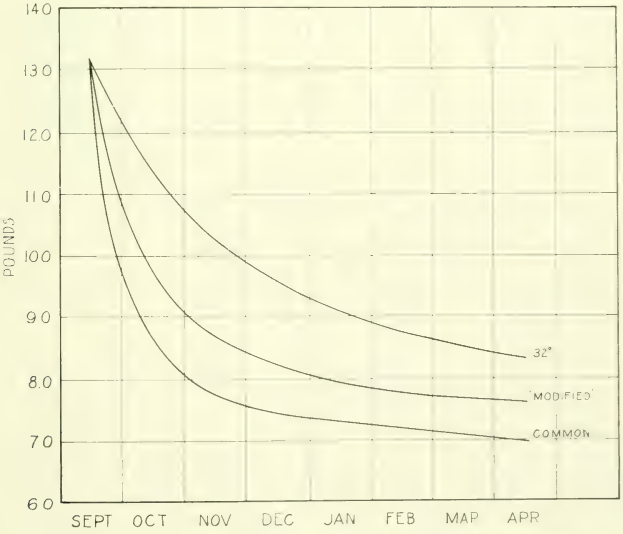


Figure 2. Rate of Ripening of Apples in Various Types of Storages, as Indicated by Pressure Test.

Humidity

Repeated experiments have shown that under cold-storage conditions a relative humidity of 85 percent is adequate to prevent shriveling. Roxbury Russet and Golden Delicious tend to shrivel more readily than varieties such as McIntosh and Baldwin, because of the absence of a waxy coating over the skin which, when present, retards the loss of moisture. Therefore, the maintenance of a relatively high humidity is of special importance where varieties of the former type are to be stored. An excessively high humidity not only is difficult to maintain but may be objectionable in that it provides favorable conditions for the development of rots and molds.

There may be some difficulty in maintaining a humidity of 85 percent in a refrigerated storage during the loading period. Continuous operation of the compressor will cause heavy frosting of the coils, and this removal of moisture from the air may reduce the relative humidity to as low as 70 percent. Usually there is no difficulty in bringing up the humidity when the initial cooling of the fruit is completed.

The most satisfactory method for determining humidity is by means of a sling psychrometer. Hair hygrometers are more convenient to read but are less accurate and require frequent checking.

During the season of 1935-36 an experiment was conducted to determine what effect this low humidity might have on the subsequent condition of the fruit. Three lots of McIntosh apples were stored at 32° but at different humidities from September 27 to November 23, after which they were all stored at 85 percent relative humidity. The conditions under which the various lots were stored and the loss in weight of each are shown in Table 1, and the losses are shown graphically in Figure 4.

Table 1. — Loss of Weight of McIntosh Apples Stored under Different Conditions.

Lot No.	Relative Humidity (Percent)		Loss in Weight (Percent)		
	Sept. 27– Nov. 23	Nov. 23– May 5	Sept. 27– Nov. 23	Nov. 23– May 5	Total
1	65	85	1.8	0.9	2.7
2	70	85	1.8	0.9	2.7
3	85	85	0.8	1.6	2.4

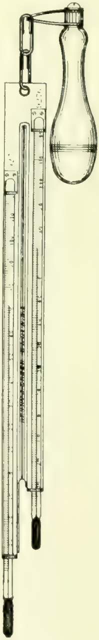


Figure 3. Sling Psychrometer.

This experiment was repeated the following year with comparable results. The data and observations from these two experiments indicate that, while there may be a slight loss of moisture from apples at low humidity, it will not cause shriveling or any appreciable injury to the fruit if it continues only while the storage is being filled.

Apples tend to lose moisture more readily in common storage because evaporation is more rapid at the higher temperatures. Therefore, a relative humidity of not less than 85 percent should be constantly maintained in a common storage.

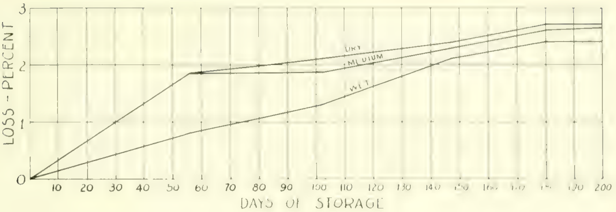


Figure 4. Loss of Weight of Apples Stored at Various Humidities.

Ventilation

As apples ripen they give off considerable quantities of carbon dioxide and smaller amounts of other gases. Unless these gases are removed as they are produced, they tend to accumulate in relatively high concentrations around the apples to the exclusion of oxygen, which is essential to the normal respiration of the fruit. These conditions may impart undesirable flavors to the fruit and promote the development of apple scald. Consequently, every storage house should be provided with some means by which fresh air may be introduced into the rooms.

TYPES OF STORAGE

Farm storages are of two classes: air-cooled or "common" and mechanically cooled or "cold."

Air-cooled storages are always located on the farm. They are usually small in size and inexpensive to build and maintain. The grower whose production and market conditions are satisfied by air-cooled storage is not justified in constructing a more expensive type. Temperatures normally obtained in common storages in New England and temperatures maintained in refrigerated storages are shown in Figure 5.

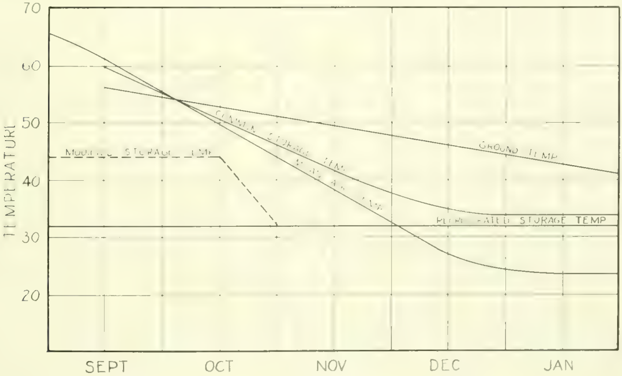


Figure 5. Ground, Air, and Storage Temperatures.

Refrigerated storages are often located on farms but sometimes are built at central points to offer custom service to a group of growers. They vary greatly in capacity from 2,000 bushels to 100,000 bushels or more.

Before deciding to build a refrigerated storage a grower would do well not only to consider the advantages of a farm-located storage as listed in this bulletin, but to examine carefully the economic features involved. If building solely for individual use, the storage should be limited in capacity to about 60 percent of the present or expected average production.

The advantages of a farm-located storage are:

1. Apples go into storage promptly after picking. With early and mid-season varieties the harvest date coincides with relatively warm weather, so that ripening or softening proceeds very rapidly after picking. With late varieties this factor is not so important.
2. Apples go into storage with a minimum of handling and hauling.
3. The fruit is under the direct care of the owner and being near at hand may be graded and packed more conveniently than if located in a distant storage. With present transportation facilities most farms are relatively close to market outlets.
4. Apples may usually be stored on the farm at a lower cost than in a commercial storage. The commercial storage located in the city has heavy overhead charges due to high land and building costs, with high labor and management expenses. These costs are reduced to a minimum in a farm storage. Estimates of storage costs are given in the sections dealing with common and refrigerated storages.

AIR-COOLED STORAGE

It is inadvisable to depend on air-cooled storage for holding McIntosh apples later than January 1, or Baldwin or other late varieties after March 1, but many small growers catering to local trade, either roadside stand or retail store, are successfully holding apples in air-cooled storage for the periods mentioned and selling satisfactory fruit at market prices. Fruit from air-cooled storages going into market in competition with cold storage fruit usually, although not always, sells at lower prices.

Requirements of Common Storage

Four conditions must be met in providing an efficient air-cooled storage.

1. The structure must be frost-proof.
2. The building must be rat-proof.
3. Provision must be made for cooling the room quickly with outside air.
4. Provision must be made for maintaining adequate humidity.

These structures may be frost-proofed by earth embankments or by insulated construction above grade. Protection against rats or other rodents can be provided by the use of hardware cloth or sheet metal. Cooling and ventilating may be done in one of three ways: (a) by natural air movement, (b) by an exhaust fan, or (c) by a fan to blow air into the room. Adequate humidity may be maintained by the natural moisture of a damp earth floor or by sprinkling.

In most instances air-cooled storages are developed by renovating and remodeling barn basements or abandoned cellar holes. Sometimes an aboveground building is used. Occasionally new buildings are built for this purpose.

Remodeling a Barn Basement

The first operation in adapting a barn basement to storage use is to clean out the space thoroughly. The earth floor should be removed to a sufficient depth to eliminate all foul soil. It is desirable to excavate to at least 12 inches below finish grade and then fill with gravel or other earth. If a concrete floor is to be laid, gravel should be used for this fill. Advantages of a concrete floor are that it can be kept clean, which is impossible with an earth floor, and that it gives a solid, level surface on which to stack and handle the fruit.

It is desirable that the height of the room be not less than 8 feet. Many of these rooms have been built less than 8 feet high and have proved satisfactory, but 8 or even 10 feet is a convenient height for filling and for air circulation.

Many old basements have walls that do not extend down to the desired grade, and in such cases a retaining wall of concrete or stone should be put in to hold the earth beneath the original wall.

Holes in the wall should be closed, either by troweling mortar into the crevices or by pouring a concrete face over the whole surface. If there is a probability of sometime making the room into a refrigerated storage, the latter method is better. The concrete face should be thick enough so that no stone in the wall projects into the room.

In most old basements many of the posts that support the ceiling will need resetting on new piers, which may be large stones or poured concrete. The piers should be carefully set with tops at floor level.

Most old barn cellars have three walls and an open side. In developing a storage, it is necessary to build a wall on this open side. This wall should have a concrete or masonry foundation extending 15 or 18 inches below the established floor level and high enough above the floor grade to prevent the entrance of surface water. The wall itself should have 2″ x 6″ studs covered on the outside with wire cloth, paper, and weather-proof material, and on the inside with paper and sheathing. The wall is filled with insulating material, either planer shavings, granulated cork, or one of the many prepared insulation fills.

In building the new wall on the open side of the cellar, it is necessary to give consideration to the matter of doors and ports. Individual preference and conditions will determine the number and location of these openings, but it is desirable that they be few in number and small in area. In a storage with a 50-foot wall, one 4-foot door and two ports each 24 inches square for loading and unloading will be adequate. Doors to ports and entrances should be insulated.

The ceiling of the room should be insulated and made rat-proof. This is usually done by covering the underside of the joists with wire cloth, paper, and sheathing. It is possible to combine two of these in the form of steel sheets which will shut out rats and make an excellent carrier for the fill between the joists. Steel sheets are usually less expensive than the combination of wire cloth and sheathing. The space between the ceiling joists is packed with fill insulation: either by taking up the floor above the joist and re-laying it after filling or by putting on the ceiling and packing in the fill a section at a time.

No additional frost-proofing will be necessary on the underground foundation walls. Walls which are not fully banked should be regraded to the top of the wall.

Remodeling an Aboveground Structure

In making a storage from an aboveground structure, the first operation is to clean out the space and take up the floor unless, as sometimes happens, the building has a concrete floor. Wooden sills should be carefully examined and replaced wherever necessary.

Above ground buildings must be insulated on the sides as well as ceiling, which can best be done by using fill insulation.

Most of these structures were framed with main timbers 8 inches square, which provides easy opportunity for adequate insulation. In cases where the timbers are less than 8 inches they should be furred out to that dimension.

Usually the first scaffold above the floor in barns is not as high as is desirable for a good storage. It is advisable to remove low scaffolds and put in a ceiling at a height of 10 feet. The outside of the building should be made watertight. The inside surface of the outer wall between joists or girts should be covered with waterproof paper and then, if necessary, the space between main timbers studded out to a line with these timbers. These studs may be light stock such as $2'' \times 4''$ spaced 30 inches on centers. The inside face of frame is covered with wire cloth, paper, and sheathing or with paper and steel sheets and the insulating fill put in place. The ceiling is covered and insulated in the same manner as the walls.

New Structures

New structures for common storage use may be either one- or two-story buildings. If two-story, the lower one is usually below grade. A one-story building is most frequently built of frame, with concrete foundation and floor. In a two-story structure, the walls are usually concrete below grade and frame above.

The planning of such a building is a matter which calls for the assistance of someone familiar with structural problems.

Packing Space

A good packing room is so located and built as to provide a maximum of natural light, efficient handling of fruit from and to storage rooms and trucks, comfortable working conditions during cold weather, and adequate artificial light when necessary. It is large enough to provide space for a grading machine and to permit stacking of such volume of fruit as may be going to market direct from the packing table.

A common and satisfactory method of providing packing space is to add a shed on one side of the storage room. This type of packing room is best because it is easy to move apples back and forth from the storage and it is possible to get adequate daylight by means of windows and skylights.

Where no grading machine is to be installed, a 16-foot width is satisfactory and the shed may be built without posts. If a grading machine is to be set up, the width should be not less than 20 feet and posts will be necessary to support the roof.

Another way to solve the problem of packing space is to have a room located over the storage. This may in some cases be less expensive than building the shed beside the storage, but there is one disadvantage — all the apples to be packed from storage must be hauled or lifted upstairs.

The upstairs location is to be preferred to using space in a cellar for the purpose since natural light is difficult to obtain in below-grade rooms.

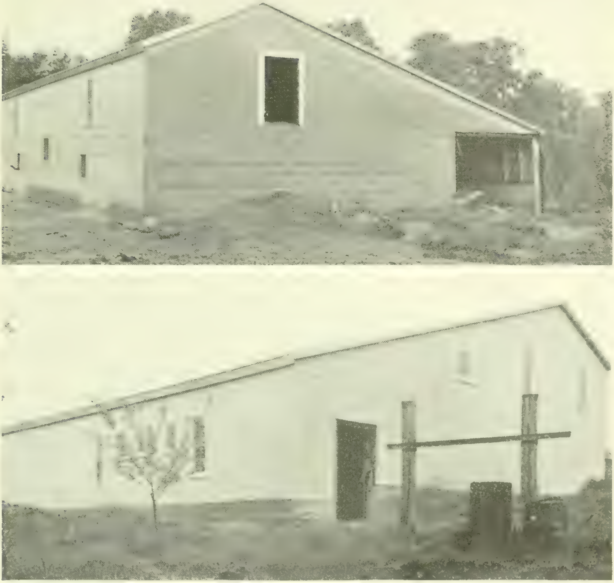


Figure 6. Air-cooled Storage.

New one-story building of frame construction insulated with ten inches of shavings; metal roof and asbestos shingle covering on walls; box storage above; packing room and truck stand along one side, separated by a partition.

The center opening on long wall in upper view shows inlet to fan, and the ports near ends are used as outlets for warm air as well as for loading ports.

The lower view shows windows in packing room.

Cooling and Ventilating

Three types of cooling and ventilating equipment are available: viz., natural air movement, exhaust fan, and intake fan. The most commonly used has been the exhaust fan, but recent experiments and practice indicate that the intake fan is as good or better and is less expensive to install.

The exhaust fan system consists of a fan of proper size, installed just beneath the ceiling in the center of one wall, and inlet openings at the floor level on the opposite wall. The combined area of the inlets should be twice the area of the fan. The fan should have a capacity to give a complete air change every five minutes. That is, a room 40′×60′×10′, having a capacity of 24,000 cubic feet should have a fan capable of moving 4,800 cubic feet per minute. This is a fan capacity of ½ cubic foot per minute per bushel of apple capacity.

Table 2. — Fan Sizes.

Storage Size (inside)	Cubic Feet	Capacity Bushels	Fan Size Inches
22′×22′×8′	3,872	1,500	10
22′×33′×8′	5,808	2,300	12
33′×33′×8′	8,712	3,500	16
33′×44′×8′	11,616	4,600	20
44′×44′×8′	15,488	6,000	24

The more recently developed practice of driving in cold air and building up pressure to force it down through the stacks of apples and finally out through ports at the same end of the room as the fan, is a reverse of the exhaust-fan practice. In this system the fan is located just beneath the ceiling in the center of one wall, so set that outside air is forced into the room. The outlet ports are placed on the same wall as the fan and just above the floor level. The sizes of fan and ports are the same as recommended in the exhaust system.

Storage Costs

A good air-cooled storage may be provided at an initial outlay of from twenty to fifty cents per bushel of capacity. This variation is caused by the fact that some storages are adapted from an existing structure, while others are built new.

Using fifty cents per bushel of capacity as a cost figure and a 3,000-bushel capacity as an example, storage costs will amount to about five cents per bushel per year, including interest, depreciation, taxes, and other charges.

REFRIGERATED STORAGE

In planning a new cold storage, the owner must frequently adopt a design which will conform to existing buildings and also fit the specific location on which it is to be placed. Where local conditions permit, it is desirable to have a nearly square structure. The building which will give the least wall, floor, and roof area per cubic foot of volume is the ideal type, as this requires the least insulation material and has the lowest heat loss. While a cube meets these requirements most nearly, it is seldom that this shape can be used in practice. It is desirable, however, to approximate a square building rather than a long, narrow one and rooms should be made as high as convenience in use and reasonable floor loads will permit. A ground-floor storage should be not less than 10 feet high, and many growers use rooms 15 feet high with apparent satisfaction. On many New England farms it is possible to fill the building from two levels, and this simplifies the loading of high rooms and upper stories. High rooms are partly filled from the lower level and then the upper part of the room is filled through a port located near the ceiling on the upper grade side, the apple boxes being run into the building on roller track. Upper floor rooms are usually made not more than 10 feet high, as greater height requires very heavy floor construction.

Floor Load

The actual floor load will vary with the height of room, amount of space left above apples, type of container, and closeness with which the boxes are stacked. If a space of about one foot is left above the apples, which are stored loose as received from the orchard, the floor load will be approximately as indicated in Table 3.

TABLE 3. — FLOOR LOAD.

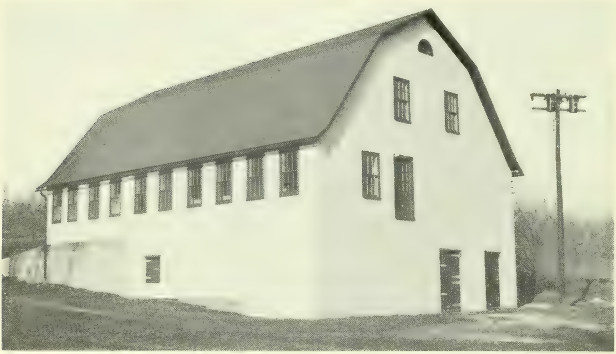
Height of Room in Feet	Pounds per Square Foot
8	165
10	210
12	260

In planning the building it is necessary to allow 2½ cubic feet of room space per bushel of apples to be stored. This allows for alleys, space above apples, and room for blowers or coils.

An ideal building for a cold-storage plant is some type of masonry structure. In many cases, however, the first cost of these permanent buildings is considered too high, and frame construction is used. Many storages are obtained by remodeling existing structures.

Doors and Ports

Openings into the cold storage rooms should be kept at a minimum. Apples are usually moved in and out of the storage through ports 24 inches square, the boxes being moved on roller track. The sill of the port is placed not less than 24 inches above the storage floor and where possible should be at truck floor height or higher above outside grade.



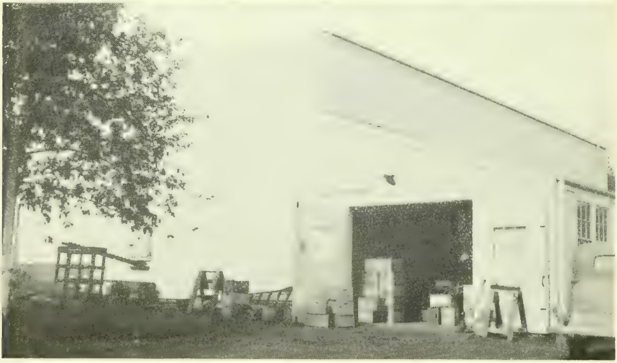


Figure 7. Refrigerated Storages.

Upper: New 13,000-bushel frame storage. Apples stored on lower floor and on half of upper floor; packing room in other half of upper floor; box storage in attic; shipping platform to be added in front end. Concrete walls and floor insulated with sheet cork, and frame walls and ceiling with regranulated cork. Storage cooled with a single blower located on the first floor, with ducts to second floor.

Lower: Two-story storage with packing room along one side. Frame construction, insulated with regranulated cork, except back wall which is underground. This wall is made from concrete and insulated with sheet cork.

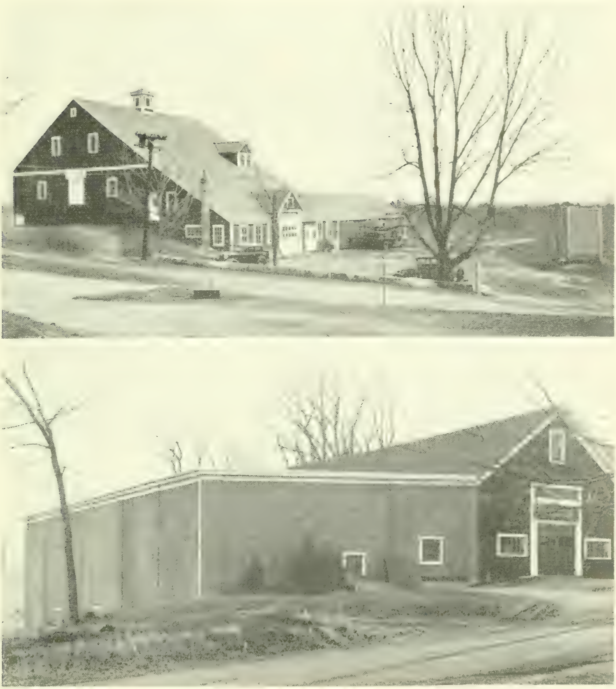


Figure 8. Refrigerated Storages.

Upper: One-story 13,000-bushel storage remodeled from basement of dairy barn. Barn floor raised to give fourteen-foot ceiling height. Packing room along side of storage. Cooled with one blower and four-inch by four-inch ammonia compressor. Floor and masonry walls insulated with sheet cork, and frame walls and ceiling with regranulated cork. Cooling tower shown at the extreme right of the picture.

Lower: Two-story storage of concrete construction, stucco finish, insulated with sheet cork. Packing room along second floor of storage. Apples carried by truck from lower floor to packing room.

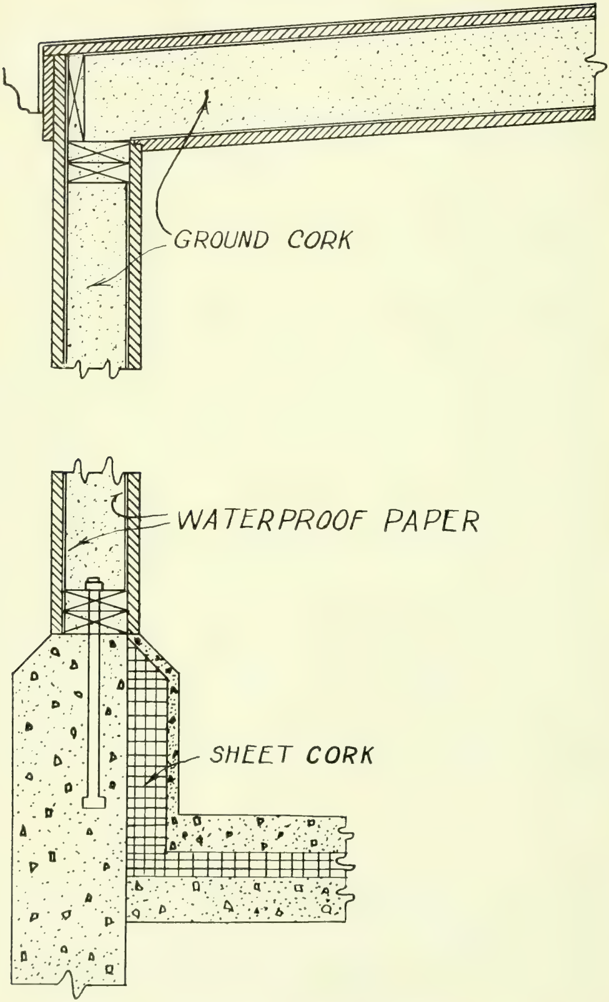

GROUND CORK
WATERPROOF PAPER
SHEET CORK

Figure 9. Section Showing Sill, Floor, Wall, and Ceiling Construction.

Insulation

No matter what type of building is used, it must be well insulated to make a satisfactory storage. Frame buildings are commonly insulated with fill insulation, as the space for the fill is partially provided in the normal construction of the building. The most common materials are ground cork, manufactured fibrous materials, and shavings, all of which are good insulators provided they remain dry. Every effort must be made to prevent the entrance of moisture, and the common means for doing this is to line the surface enclosing the insulation with waterproof paper. The chief source of moisture is from the air entering the insulation through the outside walls. This moisture is deposited when warm air comes in contact with the cold insulation. Continuous condensation from the outside may eventually moisten the insulating material so much that it loses a great deal of its insulating value.

The heat transfer through a few types of building construction is given in Table 4. The values under "C" give the number of British thermal units which will pass through one square foot of area per hour per degree of temperature difference. By using this coefficient, it is possible to determine heat leakage for any set of assumed temperature conditions. The columns under "Tons" indicate refrigeration load per 100 square feet for two storage temperatures, with normal air and ground temperatures for New England at apple harvest time.

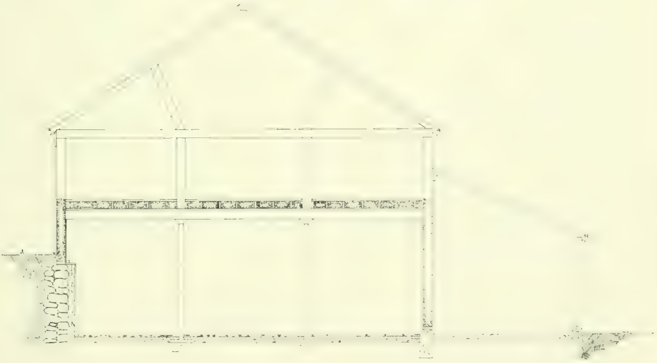


Figure 10. Remodeled Structure.

Basement storage ten feet or more high obtained by raising old ceiling. Packing shed added on side. Second story used for box storage.

Regranulated cork and many other types of fill insulation when installed under ideal conditions have as high insulating values as corkboard. In refrigeration practice, however, it is customary to use two inches of fill insulation as equivalent to one inch of corkboard. This is to allow for imperfect packing of the insulation material, settling, and possible absorption of moisture.

The standard floor construction for apple storages consists of a base of 3 inches of concrete on which 2 or 3 inches of corkboard is laid in asphalt. The top of the cork is mopped with asphalt, and a 3-inch concrete wearing floor is laid on top of the cork.

It is desirable to provide from 6 to 8 inches of fill insulation for frame walls, and frame roofs are usually insulated with 8 inches of granulated cork or other fill insulation.

TABLE 4. REQUIRED REFRIGERATION TO OVERCOME HEAT LEAKAGE PER 100 SQUARE FEET OF AREA.

(Based on an outdoor air temperature of 75°, except roof at 85°, and ground temperature of 56°.)

Construction	C*	Tons, Refrigeration			
		32° room		45° room	
Concrete floor:					
4" slab	.90	.1800		.0825	
3" slab, 3" finish	.79	.1580		.0725	
3" slab, 3" finish, 2" corkboard	.13	.0260		.0118	
3" slab, 3" finish, 3" corkboard	.09	.0180		.0082	
3" slab, 3" finish, 4" corkboard	.07	.0140		.0064	
Roof:					
1" sheathing, 2" corkboard, tar and gravel roof	.12	.0530		.0400	
1" sheathing, 3" corkboard, tar and gravel roof	.09	.0398		.0300	
1" sheathing, 4" corkboard, tar and gravel roof	.07	.0309		.0233	
1" sheathing, 6" granulated cork,** roof boards and covering	.09	.0398		.0300	
1" sheathing, 8" granulated cork, roof boards and covering	.07	.0309		.0233	
		Below Ground	Above Ground	Below Ground	Above Ground
Concrete wall:					
6" wall	.79	.1580	.2830	.0725	.1975
12" wall	.60	.1200	.2150	.0550	.1500
6" wall, 2" corkboard	.13	.0260	.0466	.0118	.0325
6" wall, 3" corkboard	.09	.0180	.0322	.0082	.0225
6" wall, 4" corkboard	.07	.0140	.0251	.0064	.0175
12" wall, 2" corkboard	.12	.0240	.0430	.0110	.0300
12" wall, 3" corkboard	.08	.0160	.0287	.0073	.0200
12" wall, 4" corkboard	.06	.0120	.0215	.0055	.0150
Frame wall:					
6" granulated cork	.09	—	.0322	—	.0225
8" granulated cork	.07	—	.0251	—	.0175

*"C" is the number of B. t. u. which will pass through one square foot of material per hour per degree of temperature difference.

**Granulated cork under ideal conditions has no higher heat transfer than corkboard. Under ordinary conditions of installation the space may not be completely filled with cork. For this reason the heat transfer through granulated cork is given as twice that through corkboard. There are a number of commercial insulation fills having a heat transfer coefficient approximately the same as granulated cork. Dry planer shavings are about three-fourths as effective as granulated cork for insulating.

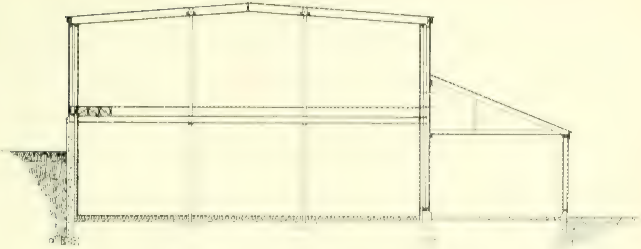


Figure 11. Two-story Storage with Packing Room.

Concrete wall below ground insulated with sheet cork. Frame construction above ground insulated with fill insulation.

Corkboard is the accepted type of insulation for masonry construction. Exposed masonry walls are commonly insulated with 3 inches of corkboard and walls below grade, with 2 or 3 inches. In new high grade masonry construction, roofs are usually insulated by laying 4 inches of corkboard on top of the flat roof deck, and the cork is protected with a tar and gravel roof.

Sheet corkboard walls are protected either by a double coat of portland cement plaster or with a mastic prepared specifically for this purpose. The latter is probably fully as effective for sealing against moisture, while the former is stronger and serves as a better protection against mechanical injury. Ceilings in some cases are protected with plaster, although more commonly with a mastic finish.

Principles of Mechanical Refrigeration

All mechanical refrigeration systems depend for their operation on the fact that a liquid absorbs heat on evaporation. On this principle, a liquid having a low boiling point is allowed to expand into a set of pipes in which a relatively low pressure is maintained. The liquid evaporates at this low pressure and abstracts heat from the walls of the pipe, thus cooling the air or liquid surrounding the pipes. A *compressor* draws the vapor from the *evaporating coils*, keeping them at a low pressure, and forces it into another set of coils known as the *condenser*

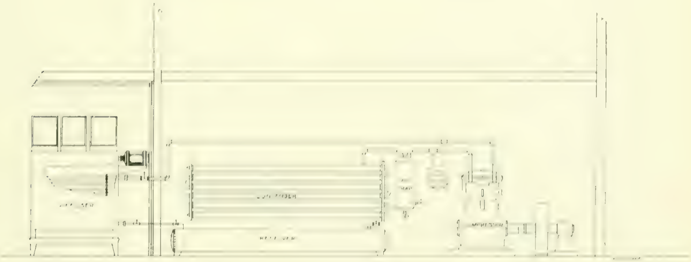


Figure 12. Diagram of Refrigeration System.

which is maintained at a relatively high pressure. The combination of high pressure and low temperature in the condenser serves to return the vapor to a liquid form. The condenser is cooled by air in the small models and with cool water in the larger sizes.

Refrigerants

There are a number of substances which can be used in the refrigeration cycle. These are known as refrigerants. Those commonly used in cooling apple storages are ammonia, freon, methyl chloride, and sulfur dioxide. Their properties differ considerably but all can be used with reasonable success. Ammonia operates at considerably higher pressure than the other refrigerants and must be kept in iron, steel, or aluminum pipes as it attacks copper and copper alloys. For other refrigerants, evaporating and condensing coils made from copper or copper alloy can be used. These are made up at lower cost than steel units. Ammonia requires a somewhat smaller compressor than the others and the power requirements are slightly less; but for all practical purposes it can be assumed that the same power will be required with all refrigerants. The pressure-temperature characteristics of the common refrigerants are given in Table 5.

TABLE 5. — PRESSURE–TEMPERATURE CHARACTERISTICS OF THE COMMON REFRIGERANTS.

Refrigerant	Gauge Pressure in Pounds		Relative Size of Compressors
	At 5 ° F.	At 86 ° F.	
Ammonia	19.6	154.5	1.0
Freon	11.8	93.2	1.80
Methyl Chloride	6.1	80.8	1.82
Sulfur Dioxide	5.9*	51.7	2.45

*Inches of vacuum.

Large apple storages are cooled with ammonia, while the small ones use low-pressure gases. At present the dividing line seems to come at about five tons capacity, but the low-pressure refrigerants are gradually encroaching on territory formerly held by ammonia. Apparently both lines of equipment are giving satisfaction in their respective fields. Blower and piping costs are lower with low-pressure systems, inasmuch as copper piping can be used; but the compressor is usually more expensive, so that the total cost of the two types does not differ a great deal.

Rating

The capacity of refrigeration units is measured in terms of tons. A one-ton machine is one which will produce the same cooling effect in operating 24 hours as is obtained when one ton of ice is allowed to melt. As each pound of ice takes up 144 B. t. u. (British thermal unit) in melting, the melting of one ton of ice will absorb 288,000 B. t. u. One B. t. u. is the heat required to raise the temperature of one pound of water one degree Fahrenheit. A one-ton machine, therefore, removes heat at the rate of 288,000 B. t. u. per 24 hours, or 12,000 B. t. u. per hour.

Cooling Water

The heat removed by the refrigeration equipment is finally carried away by the cooling water. Where the water is allowed to go to waste after flowing through the condenser and the compressor, at least 2 gallons of water per minute per ton of refrigeration capacity is required. When this amount of water is not available, it will be necessary to cool the water after it comes from the condenser for recirculation. This can be done by spraying it into a pond or into a spray tower. The spray brings the warm water in contact with the air and permits some of the water to evaporate. This serves to cool the remainder. The degree to which the water is cooled depends upon the effectiveness of the spray nozzles and the temperature and relative humidity of the air. The spray system is most effective on clear, cool days; but if the spray tower is of ample size, it will give satisfactory service even on warm, muggy days. It is customary to circulate 5 gallons per minute per ton of refrigeration load when a spray tower is used.

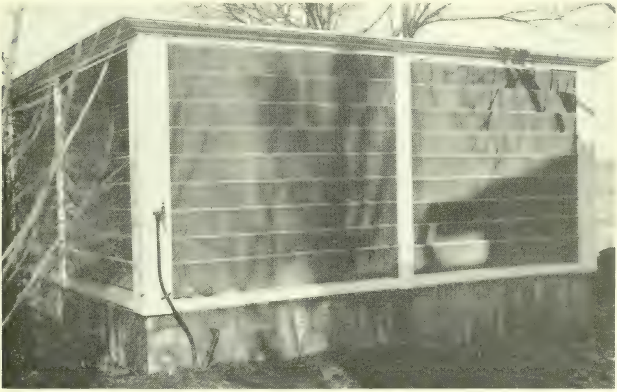


Figure 13. Cooling Tower.

Concrete curb and floor with wooden louvers. Two spray nozzles.

Where a limited amount of water is available, an evaporative-type condenser is sometimes used. Condensers of this type are built like an automobile radiator, and a spray of water is thrown against the outside of the condenser. The evaporation of some of this water serves to cool the refrigerant.

Cooling Equipment within the Storage Room

Until recent years cooling systems in apple storages were evaporating coils over which the air moved by natural circulation. These coils are usually made up so as to extend practically the whole length of the room, but there are various ways in which the coils may be arranged. In narrow rooms coils are placed on the two long walls, with a number of pipes placed one above the other. In wider rooms the wall coils are supplemented by similar coils hung in alleys running lengthwise of the room. In another arrangement pipes are assembled in groups or bunkers extending the full length of the room and hung near the ceiling. In all cases drip pans must be provided to catch the drip from the coils. The cold air drops to the floor underneath the coils, spreads out over the floor and, as it is warmed, rises in the spaces between the boxes. This system is quite satisfactory provided boxes are piled so as to leave a small space — one to two inches — between alternate rows. Naturally, boxes near the floor will cool off more rapidly than those at the top of the stack.

Most new storages are equipped with blowers, sometimes called "diffusers." In large rooms, 4000-bushel capacity or more, floor-type blowers are used, while in the smaller rooms the blowers are suspended from the ceiling. The floor-type blower consists of the evaporating coil enclosed in a sheet-iron casing. A fan mounted at the top of the case draws air from the floor up through the coils and discharges the cooled air at high velocity near the ceiling. The small blowers are similar in general design to an automobile radiator, the air being drawn or forced across the cooling coils horizontally.

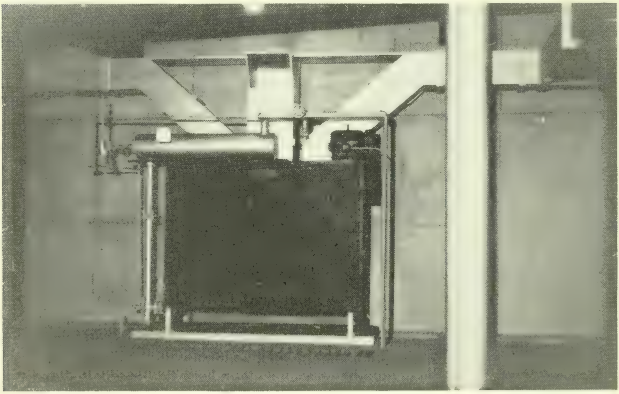


Figure 14. Floor-type Diffuser or Blower with Wooden Flues.

Blowers have an advantage over wall or ceiling coils in that a positive air circulation is set up, which insures more uniform temperature throughout the storage; and with a relatively high air velocity over the fruit the heat is removed more rapidly. When blowers were first introduced, it was thought that this rapid air circulation would dry out the fruit and cause shriveling. Extensive observations made on fruit cooled by blowers indicate that this does not happen if a relative humidity of not less than 80 percent is maintained.

Where the blower cools a single room, the air is driven across the top of the stack of boxes, filters down, and is drawn through the stack of fruit to the inlet at the base of the blower. Where two rooms are cooled by a single blower (Fig. 15), the air leaving the blower is divided between the two rooms, D and D_2, the return from the second floor being through an opening in the floor shown at C. Dampers regulate the flow of air to the two floors. In many two-story buildings blowers are placed on each floor. The arrangement shown in Figure 15 is to be preferred, even though two blowers are required to carry the load, as it permits throwing the full cooling capacity into whichever room needs it most. It is highly desirable that all the blowers operate whenever the compressor is operating, in order to maintain a relatively high refrigerant temperature and to assure maximum output from the compressor. If a storage is equipped with two blowers and only one is operating at a given time, less refrigerant is available to fill the cylinders of the compressor than if both blowers were operating. This gives low pressure and temperature in the coil and reduces the refrigeration capacity of the machine.

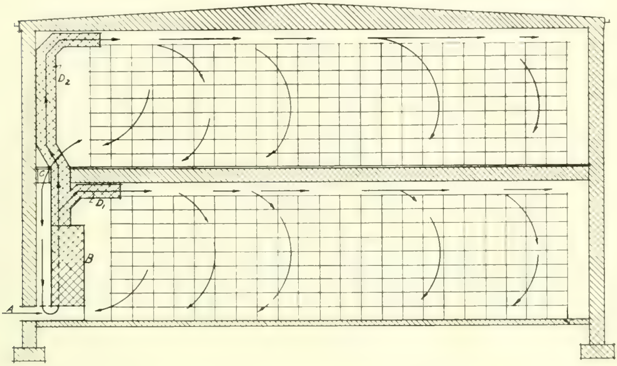


Figure 15. Arrangement of Air Circulating Equipment for Two-story Apple Storage.

The air circulation is most effective if no alleys are provided within the room. Alleys parallel to the direction of air travel act as flues, permitting the air to return to the blower with consequent reduction of circulation through the stacks. Where alleys parallel to air travel are necessary, they should be closed with a canvas or sheet of wallboard near the blower. Alleys crosswise to the direction of air travel act as traps and permit the air to return to the blower without going to the rear of the room. This can be prevented by covering the alleys with canvas or sheets of wallboard.

When the length of air travel exceeds 40 feet, it is advisable to install one or more ceiling ducts extending about half the length of the room to insure adequate air circulation near the far end of the room.

Blowers should preferably be placed so that the air travel is parallel to the girders within the rooms, as air currents are deflected when they strike an obstruction such as a girder. A space of 12 inches should be left between the top box and the ceiling of the room. Boxes should be piled on ¾-inch strips laid on the floor to permit air circulation between the floor and the boxes.

Estimating the Refrigeration Load

In estimating the required refrigeration capacity for an apple storage, it will be found that the cooling of the fruit makes up the greater portion of the load. In order to estimate the load, it will be necessary to make certain assumptions. As an illustration, it will be assumed that 10 percent of the capacity of the storage is harvested each day; that apples are brought in at a temperature of 75°; and that average air temperature is 75° and ground temperature, 56°. It is further assumed that loose apples weigh 45 pounds per bushel, including the container, and have a specific heat of .90.

The refrigeration capacity required to cool 1000 bushels per day is determined as follows: 1000 bushels of apples weigh 45,000 pounds and, having a specific heat of .90, they will give up .90×45,000, or 40,500 B. t. u., when the temperature is lowered one degree. When cooled from 75° to 32°, the temperature drop is 43°, and a total of 43×40,500 or 1,741,500 B. t. u. will be given up.

In addition to the sensible heat covered by the above calculations, it is also necessary to remove the heat of respiration given off by the apples. The rate at which heat of respiration is generated depends upon the temperature at which apples are stored. Apples stored at 60° give off from 100 to 150 B. t. u. per bushel per day, while at 32° the rate is from 15 to 20 B. t. u. per bushel. As a storage is filled, the heat of respiration to be removed, of course, will increase from day to day, with the greatest amount on the last day of loading. If we assume that the storage is filled in 10 days, the greatest amount of heat will be given up on the 10th day. The daily refrigeration load is about 200 B. t. u. per bushel harvested each day if the storage is carried at 32°, and about 400 B. t. u. if the storage is held at 45°. In the problem we have assumed, cooling 1000 bushels a day to 32°, it will be necessary to allow 200,000 B. t. u. for heat of respiration which, when added to 1,741,500 B. t. u. of sensible heat, gives a total of 1,941,500 B. t. u. Inasmuch as a one-ton machine will remove 288,000 B. t. u. in 24 hours, a capacity of 1,941,500÷288,000, or 6.7 tons, is required.

If the apples are to be cooled to 45°, the temperature reduction will be 75° minus 45°, or 30°, making the total sensible heat to be removed 30×40,500, or 1,215,000 B. t. u. The heat of respiration will be 400×1000, or 400,000, and the total heat to be removed per day will be 1,215,000+400,000, or 1,615,000 B. t. u. This divided by 288,000 gives a total refrigeration capacity of 5.6 tons needed to cool 1000 bushels per day.

In order to estimate the heat leakage into a storage, we will assume a one-story building 40 feet wide, 42 feet long, and 10 feet high. The walls are of concrete, 6 inches thick and insulated with 3 inches of sheet cork, and half of the wall area is underground. Standard concrete floor construction is used, with 2 inches of sheet cork. The roof is insulated with 4 inches of sheet cork. The heat leakage into this room is shown in Table 6, the data being obtained from Table 4.

In this example no allowance has been made for air infiltration or the opening of doors. The heat loss due to this cause, however, is relatively small in a fair-sized storage, particularly if apple boxes are moved through ports on roller conveyors. There is an additional refrigeration load due to the condensation of moisture and subsequent freezing on the cooling coils, but this also represents a small loss and can be neglected in rough calculations when air changes within the storage are kept at a minimum.

Men working within the storage give off heat at the rate of 500 B. t. u. an hour. This amount of heat is so small that ordinarily it need not be considered in estimating the refrigeration load.

TABLE 6. — HEAT LEAKAGE.

Construction	Area in Square Feet	32° room		45° room	
		Tons per 100 sq. ft.	Total tons	Tons per 100 sq. ft.	Total tons
Floor, 2″ corkboard . . .	1680	.0260	.4368	.0118	.1982
Walls, underground, 3″ corkboard	820	.0180	.1476	.0082	0672
Walls, aboveground, 3″ corkboard	820	.0322	.2640	.0225	.1845
Roof, 4″ corkboard	1680	.0309	.5200	.0233	.3914
TOTAL HEAT LEAKAGE, TONS			1.3684		.8413
or Roughly			1.4		.85

Electric lights and motors operating within storage rooms give off heat which has to be absorbed by the refrigeration unit. Lights develop heat at the rate of 341 B. t. u. per 100 watts an hour. Since relatively few lights are used in an apple storage and as they do not burn continuously, the heat from this source can also be neglected. A one h. p. electric motor generates about 3000 B. t. u. an hour, or the equivalent of ¼ ton of refrigeration. Motors on cooling units operate continuously during the loading period, and hence it is necessary to allow an additional refrigeration capacity of ¼ ton for each motor-horsepower used on cooling units above that required to overcome heat leakage and to remove the heat from the apples.

A room 40′×42′×10′ has a volume of 16,800 cubic feet. Allowing 2½ cubic feet per bushel, the capacity of the room is 6720 bushels. If the storage is filled in ten days, the daily loading will be 672 bushels. It was determined that the refrigeration load in cooling 1000 bushels of apples to 32° under the assumed conditions is 6.7 tons. To cool 672 bushels would require .672×6.7, or 4.5 tons. In like manner it would require .672×5.6 or 3.75 tons to cool the 672 bushels a day to 45°. If we assume that a 2 h. p. motor is used on the cooling unit, an additional ½ ton of refrigeration must be allowed to take care of the heat given off by this motor. The total refrigeration capacity would then be as follows:

TABLE 7. — REFRIGERATION LOAD, IN TONS.

	32°	45°
Heat leakage (40′×42′×10′ building)	1.40	.85
Cooling 672 bushels a day	4.50	3.75
Heat from 2 h. p. motor	.50	.50
Total	6.40	5.10

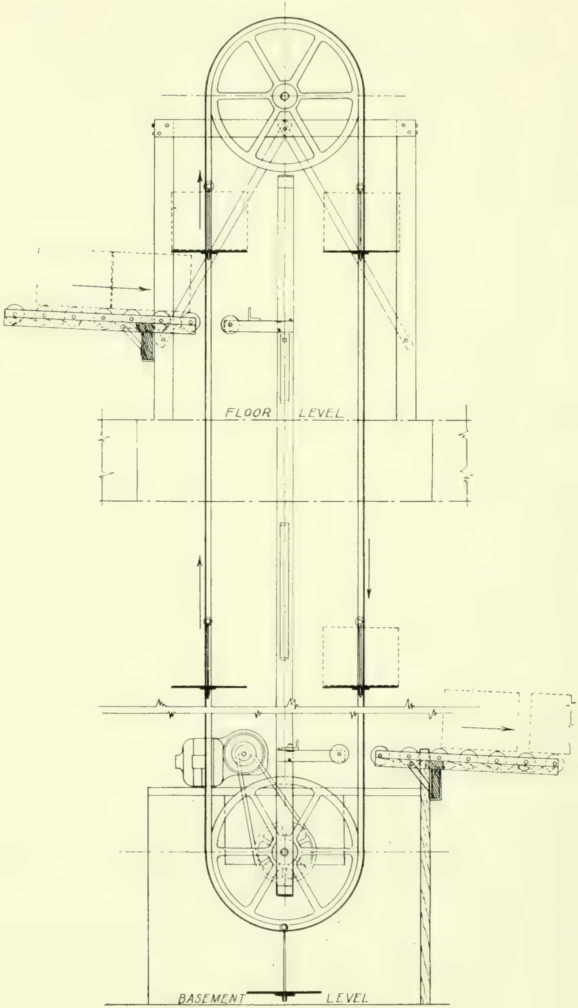

FLOOR LEVEL
BASEMENT LEVEL

Figure 16. Apple Box Elevator.

Cost of Refrigerated Storage

A refrigerated storage will cost from 50 cents to $1.00 a bushel, depending upon whether it is developed from an existing structure or built new. Large units converted from abandoned buildings have been provided at initial costs as low as 50 cents a bushel. Frame structures insulated with fill insulation have been built new for initial costs of less than 75 cents a bushel.

The annual cost of operating a refrigerated storage is made up of interest and depreciation on the building and machinery, taxes, insurance, repairs, and power. The power consumption naturally depends upon the length of the storage season, the temperature at which the storage is carried, and the effectiveness of the insulation. As a rough estimate, it can be assumed that the current consumption will be from 1 to 1½ kilowatt-hours per bushel stored. The annual cost in a 20,000-bushel storage valued at $15,000 will be about 12 cents a bushel if filled to capacity. Inasmuch as overhead (interest, depreciation, taxes, insurance) is a fixed charge and remains constant whether the storage is full or only partially filled, the annual cost per bushel will increase as the ratio of bushels stored to full capacity decreases. If the storage is only half filled, the cost will increase to about 19 to 20 cents a bushel. These figures are based on electric power at 3 cents a kilowatt-hour.

Care of Refrigeration Equipment

Refrigerating units are sufficiently complex so that actual repairs of the machines have to be made by qualified mechanics. There are, however, certain precautions and observations which should be made by the operator to insure proper functioning of the system, even though actual adjustments may have to be made by a service man. When a plant is installed, the installing engineer usually instructs the owner quite fully in its operation. Frequently, however, the instructions are not as complete as desired and at times do not cover changes which occur with continued operation. When a new man is employed, it is highly desirable that he be properly instructed in the care of the equipment.

There are certain difficulties that may develop in the operation of the refrigeration equipment which the operator should be able to recognize. Some of these he may be able to correct, while for others he must call a service man. The following is a partial list of conditions which may require attention.

Low Suction Pressure

The operator should know the proper suction pressure for his plant at different room temperatures. The suction pressure varies with the type of refrigerant used, the temperature of the storage, the relative size of evaporating unit to size of compressor, the amount of refrigerant in the system, and the amount of frost on the coils. Where two or more evaporating units are connected to one compressor, the suction pressure will vary with the number of units which are operating at any one time. If, however, the suction pressure falls off gradually over a long period of time, it may be because of leaks and loss of refrigerant. It is usually necessary to employ a service man to recharge the system. If the pressure drops considerably within a short period of time, the trouble may be due to excessive frost on the coils. The operator should have specific directions for defrosting the units, as the procedure differs with different plants.

Low suction pressure may be due to the fact that an insufficient amount of refrigerant is admitted to the evaporating coils. Enough refrigerant should be admitted to the coils so that the return pipe to the compressor is frosted up to the compressor. It is not, however, good practice to allow frost to form on the cylinders of the machine. There are various ways in which the flow of refrigerant to the coils is controlled. One method is by means of a float valve which floods the coils to a fixed level. This arrangement is very desirable and is in general use in ammonia systems. It allows the evaporating coils to operate at maximum capacity. Another method is by means of an automatic expansion valve. This type of valve is adjustable. A third method is by means of a hand-controlled expansion valve. With this arrangement any desired amount of refrigerant can be admitted to the coils, and the proper setting is obtained by watching the formation of frost on the suction pipe at its entrance to the compressor.

The capacity of the compressor is increased as the suction pressure is increased because of the greater weight of a cylinderful of refrigerant at the higher pressure. The aim, therefore, should be to carry as high suction pressure as possible to assure maximum output of the compressor. Another advantage from high suction pressure is the fact that it means high refrigerant temperature, which gives less frosting of coils than lower temperatures with less dehumidification within the room. The capacity of the evaporating units is, however, reduced as the pressure in the evaporating coils is increased. Ordinarily the refrigerant is carried from 20° to 25° colder than the room temperature.

High Discharge Pressure

The discharge pressure is dependent on the following factors: (a) size of condenser, (b) load carried on machine, (c) temperature and quantity of cooling water, (d) presence of non-condensable gases in system, (e) cleanness of condenser, and (f) amount of refrigerant in system. The operator should be informed on the discharge pressure which can be expected at different seasons of the year, in order that he may know whether the condensing system is functioning properly. If the pressure seems excessive the operator will first check on the amount of water which is being circulated. If the water is circulating normally and if the increase in pressure has been gradual, it may be that the condenser needs cleaning. The frequency of cleaning depends upon the condition of the cooling water. If the water carries a large amount of sediment, it will naturally foul the condenser more rapidly than if clear water is used. While the condenser can usually be cleaned without disconnecting any of the piping which carries refrigerant, it is desirable that a service man be on hand when an operator first dismantles the condenser. Later the operator should be able to do this job without such help.

If high pressure is not caused by lack of water, high water temperature, or a fouled condenser, it may be due to an excess of refrigerant or to non-condensable gases in the system. In the first case, it is of course necessary to remove some of the refrigerant; and in the second case the non-condensable gases are drawn off by "purging." Either of these conditions decreases the effective cooling surface within the condenser and should be corrected by a service man. Excessive pressure on the discharge side of the system puts unnecessary wear and tear on the equipment, and increases power consumption.

Leaks of Refrigerant

Ammonia leaks are easily detected by the distinctive odor of ammonia. Some other refrigerants, however, have very little if any odor and leaks may not be apparent. For these it is necessary to use certain specific tests.

Such a test may have to be used to locate the point at which ammonia is escaping, even though it is obvious that a leak exists. A wet piece of red litmus paper will turn blue if exposed to ammonia fumes, and by holding such paper near suspected points, the leak can be located with ease. The tests used with common refrigerants are listed below:

Ammonia	Litmus paper or sulfur candle
Sulfur Dioxide	Ammonia water
Methyl Chloride	Alcohol flame
Freon	Alcohol flame

If a sulfur candle is brought near an ammonia leak, a white smoke is formed. Likewise, if ammonia water is brought near a sulfur-dioxide leak, a white smoke is produced. Methyl chloride and freon give a blue-green tinge to an alcohol flame. Special alcohol blow torches are available for testing purposes.

Leaks develop usually in the stuffing boxes of the compressor shaft and in the hand valves. If moderate tightening of the glands does not stop the leaks, it is necessary to renew the packing.

Lubrication

Compressors must be supplied with a special oil, and none other should be used. Ammonia compressors have oil gauges indicating the proper height to be carried in the crank case, but in systems using other refrigerants the oil circulates with the refrigerant, and usually oil is put in only as new refrigerant is added. Specific directions should be obtained from the manufacturer for the lubrication of fans and motors.

Defrosting

In order that a refrigerating system may work efficiently, it is necessary that the cooling coils be reasonably free from frost, particularly in blowers. A heavy accumulation of frost insulates the coils and retards the passage of heat from the air to the refrigerant. The air then leaves the blower at a higher temperature than would be the case if the coils were free from frost. A heavy accumulation of frost also clogs the air passages in the blower, with the result that less than the normal amount of air is forced over the coils. This in turn reduces the amount of heat taken up by the coils.

There are three common means for defrosting:

1. Defrosting by means of a time clock, the refrigerant being shut off from the blower for a brief time at regular intervals without stopping the fan.

2. Shutting down the compressor and operating the blower fan in the normal manner and depending upon the air within the room to melt the frost. This is the same as No. 1 except that the operation is not automatic. Plans 1 and 2 are used with small plants.

3. Shutting down the compressor and operating the fan so as to draw air from outdoors over the coils. This plan warms up the storage unnecessarily and may also lower humidity.

4. Defrosting by the introduction of hot refrigerant into the cooling coils. The plan requires special piping and is the one most generally used on the larger plants where defrosting must be done in the minimum time. This method should not be used except in plants having two or more diffuser units.

SUMMARY

Storage facilities are needed on most fruit farms for the orderly marketing of the crop. Location of the storage on the farm makes it possible to put the apples in storage promptly and with the least handling, permits sorting, grading, and packing of the fruit by the regular farm help, and keeps the fruit under the care and control of the grower until it is sold.

For satisfactory operation of a storage, it is essential to have a suitable building provided with proper cooling equipment and to store only fruit having a market value which will justify the expense of storage. The conditions to be observed are listed below:

1. Fruit intended for storage should be picked at the optimum stage of maturity.

2. Apples which are to be stored for a long period — three months or more — should be of U. S. Commercial grade or better. Drops may in some years be stored to advantage for short periods.

3. Apples placed in storage should be handled carefully. They should be picked, put in the storage package, and transported from orchard to warehouse in such a manner that bruising is kept at a minimum.

4. A common storage should have the exposed walls and ceilings insulated to protect against frost and to help hold low temperatures obtained from the ground and from the circulation of cold night air. Fans should be provided for ventilation and circulation of cold air for cooling purposes.

5. In a refrigerated storage, the floors, walls, and ceilings should be insulated to reduce heat leakage. Cooling equipment of ample capacity should be installed to maintain proper temperature. Positive air circulation by fans driving air over the evaporating coils assures uniform temperature and rapid cooling of fruit throughout the storage.

6. Apples which are to be held for a long period should be stored at 32° F. McIntosh apples which are to be marketed by January 1 can be held at 45° at the time of harvest and reduced to 32° by the third week after picking. This treatment will allow the apples to develop better flavor than if stored continuously at 32°. During the storage period, relative humidity should be maintained at not less than 85 percent.

7. Fall varieties of apples such as McIntosh may be kept in common storage for short periods, particularly if they are to be distributed direct to retail dealers. Late varieties may be held for longer periods if distributed in the same manner. Apples held in common storage usually sell at considerably lower prices than similar fruit held in cold storage, if they are sold through jobbers.

8. Good management is essential to assure satisfactory operation of a cold storage. Proper temperature and humidity must be maintained, pressure gauges watched from day to day to check the functioning of machinery, coils defrosted, and equipment and rooms kept neat and clean.

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Control of Tomato Leaf Mold in Greenhouses

By E. F. Guba

This bulletin presents a description of various practices which contribute to the control of Cladosporium leaf mold, a serious foliage disease of tomatoes grown in greenhouses.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

CONTROL OF TOMATO LEAF MOLD IN GREENHOUSES

By E. F. Guba,[1] Research Professor of Botany

INTRODUCTION

Tomato leaf mold is essentially a foliage disease of greenhouse tomatoes. Outdoor tomato plantings become diseased in weather marked by periods of high temperatures and stagnant, moist air, and particularly in locations lacking good air drainage and near greenhouses contaminated with the fungus. The disease is never of general occurrence and usually is of no importance on field tomatoes in Massachusetts.

The disease is epidemic in the greenhouse in September and October on the fall or second planting of the year and before much harvest of fruit. On the spring or first planting of the year the disease often becomes epidemic in June after the last trusses have set fruit but when it is too late for the disease to do much noticeable damage to the yield. The measured loss may, however, be considerable.

The seriousness of the disease in the greenhouse is associated with high temperatures and high relative humidities prevailing during the warm months of the year. These conditions are readily obtained in a confined atmosphere of growing plants. The differences occurring between inside and outside atmospheric conditions during the year have a significant bearing on the development of the disease.

In greenhouse tomato culture in Massachusetts the monthly mean maximum temperatures are usually about 10° to 16° F. higher from May to October inclusive (corresponding approximately to the off-heating season) and usually about 20° to 40° F. higher from November to April inclusive (the heating season), than the corresponding outside monthly mean maximum temperatures. The monthly mean minimum temperatures in the greenhouse from May to October are usually about 2° to 12° F. higher than the corresponding outside monthly mean minimum temperatures. This difference increases to about 40° to 42° F. during December to February inclusive and gradually diminishes again as the season advances. This increase and decrease in the temperature difference as the outside temperatures diverge in the fall from and converge in the spring upon the inside minimum growing temperature of 60° F. significantly influence the humidity of the greenhouse air and the prevalence of the disease. In the period from May to October inclusive, boiler heating is unsteady or lacking; and in May, June, September, and October, practice allows the greenhouse temperatures to drop more or less to 50° F. In the off-heating season the monthly mean maximum relative humidity is 100 percent and the monthly average mean relative humidity is about 78 to 82 percent in contrast to a monthly mean maximum relative humidity of 80 to 94 percent and a monthly average mean relative humidity of 70 to 80 percent in the heating season, the lowest relative humidity coinciding with the coldest months. The seriousness of the disease, therefore, is associated with the off-heating or warmest months of the year when the relative humidity and temperature of the greenhouse air are at their maximum. Since the disease is not of any significance and indeed is usually absent in field plantings in this climate because of the weather peculiar to the open, it seems that outside conditions and boiler heat can be advantageously utilized, and in a manner consistent with good growth, in greenhouse management to control the disease, especially when aided by other useful contributory cultural and sanitary measures.

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[1] The writer is gratefully indebted to Dr. W. S. Ritchie and Dr. E. B. Holland of the Department of Chemistry for the chemical analyses reported in Tables 13, 15, 16, and 18, and for chemical interpretations relative to these studies.

GREENHOUSE PLANTING DISTANCES AND PRUNING

The suppressive effect of light, low relative humidity, and dry foliage conditions on the fungus and infection is recognized. Close planting and abundant plant growth encourage excessive moisture by interfering with the circulation of air. They cause undue shading and poor light. The influence of pruning and adequate spacing on air circulation and moisture removal and the penetration of light can be significant and very useful in contributing to the control of the disease. The lowest leaves of the plants always show the first signs of disease and their early removal is a desirable sanitary practice.

A planting distance of 3 feet by 14 inches in the spring growing season is commonly used in commercial practice. In the fall growing season with light conditions less favorable for plant growth and moisture conditions very favorable for the fungus, wider spacing is essential to the control of the disease. Double rows of single leader plants or single rows of double leader plants are objectionable in the spring growing season unless a generous amount of space is provided between the rows, and they are not recommended for the fall growing season. For double rows of single leader plants a distance of at least 15 inches inside between the rows and 3½ feet outside between the double rows is desirable. If the plants are grown in single rows to two leaders a distance of 4 feet between the rows and 15 to 18 inches between the plants in the rows is desirable. Wider spacing than the foregoing distances would be excessive. Whether a system of double rows of single leader plants or single rows of double leader plants is adopted, light and air conditions about the leaders will be greatly improved by staggering every other leader away from the row. Close planting or crowding does not increase yield per square foot of space. Sufficient spacing to permit light and air currents is also essential to pollination and ripening. On the other hand, the cost of excessive spacing is prohibitive. It also encourages the curling of the leaves exposed to the bright rays of the sun for long periods during the day. This unhealthy condition has now and then aroused the fear and curiosity of the grower.

After the plants have made a strong growth and before they have grown to 2 feet, the lowermost leaves can be removed. If the growth above is dense and rank, an occasional leaf on the stem can be removed. When the fruit on the lower trusses has reached full size the plants will stand more pruning below the fruit. The practice of removing the leaves below the trusses that are ripening off is desirable. (Figs. 1 and 2.) If the lower leaves are infected with leaf mold, drastic bottom pruning can aid in retarding the progress of the disease. These bottom leaves at any rate eventually turn yellow and become of no use to the plant, and might as well be dispensed with earlier. Stone (49, 50) regarded the lack of light as favorable to disease attacks in the greenhouse and advocated the removal of foliage to improve light conditions. Dyke (14) advocated the removal of foliage to improve light and undercurrents of air.

Excessive foliage pruning can be harmful to the swelling of the fruit and to good yields. Therefore good judgment is needed in providing the right balance of foliage to fruit. The heavy, free-setting varieties require vigorous, healthy foliage to insure good-sized tomatoes, so that with these types pruning must be practiced with discretion.

WATERING PRACTICES

The method of watering tomatoes under glass has a bearing on the conditions which contribute to the prevalence of leaf mold. The time of day and the character of the weather prevailing when water is applied are also very important.

Sprinkler systems wet the foliage and produce moisture conditions on the leaves conducive to the best general development of the disease. The open hose method is most generally used, but it causes the water striking the ground to splash on the foliage and offers the temptation of watering from the walks. Simple and inexpensive watering nozzles or shovels can be attached to the hose to confine the water to the bottom of the plants and these implements are used by many growers who have recognized the importance of keeping the foliage dry.

Small (42, 45) demonstrated with a few plants that the wetting of the foliage had no appreciable effect on the prevalence of tomato leaf mold. Newhall (29) asserted that a planting carefully bottom-watered is as subject to attack as one sprinkled overhead. In the writer's experiments, however, which simulated commercial greenhouse conditions, evidence of the effect of wetting the foliage on the incidence of the disease was clearly demonstrated. Two greenhouses were each divided into two equal areas. In one area the watering was done with a sprinkler system and the foliage was thoroughly wetted during each watering. The watering was done in the morning and occasionally in the afternoon. In the other area the plants were bottom-watered with a watering shovel. Leaflets from the prunings during the growing season were counted for a tabulation of the amount of infection. There were totals of 26.2 and 13.8 percent more infected leaflets in those areas where the plants were sprinkled (Table 1). The different disease conditions associated with the two different methods of watering are more clearly shown in Figure 3. These differences, while not significant under the two sets of conditions in the same greenhouse, would have been much greater if each treatment had been made in a separate greenhouse, because of attendant differences in the humidity of the air about the foliage.

TABLE 1.—COMPARISON OF OVERHEAD AND BOTTOM WATERING IN RELATION TO THE PREVALENCE OF TOMATO LEAF MOLD

Fall Cropping Season 1931.

Date of Foliage Counts	Percentage of Diseased Leaflets			
	Overhead Watering		Bottom Watering	
	House No. 5	House No. 7	House No. 5	House No. 7
October 29, 1931	85.7	85.9	78.2	77.1
December 2, 1931	96.3	85.4	75.3	66.7
January 4, 1932	100.0	100.0	80.8	94.6
January 13, 1932	100.0	100.0	47.3	85.3
Total	95.2	92.7	69.0	78.9

The wetting of the foliage contributes to the development of the disease especially if the watering is done late in the day. The experiment also showed clearly the suppressive effect on growth of sprinkling the foliage with cold water.

Impressive instances of the association of epidemics of late blight rot on tomato due to *Phytophthora infestans* (Mont.) De By., and timber rot on cucumber due to *Sclerotinia libertiana* Fckl. with sprinkler watering systems in greenhouses have also been observed. The practice is to be condemned. It offers none but a labor-saving advantage over the slower method of bottom-watering and truly is an example of false economy.

In contrast to overhead irrigation, the watering of the beds through lines of buried tile has been recommended (13, 16, 23, 34). Most greenhouse ranges in Massachusetts devoted to cucumber and tomato culture are underlaid with tile pipes for steam sterilizing which might be adapted for irrigation purposes. Subterrean watering, according to reports, exerts little if any influence on the humidity of the greenhouse air and the surface soil remains dry. This is an important factor in dealing with the disease. Ball (7) invited attention to subterranean watering through tile lines in sweet pea culture and the merit of the idea in controlling foliage diseases. Good control of tomato leaf mold has been reported where the tomatoes are grown in terraces or ridges and the water applied to intervening grooves or furrows (34, 47). In this manner only a small area of the ground is wetted.

Watering should be done on bright days when the houses can be aerated with drier outside air, although in times of prolonged dull or wet weather this rule cannot always be followed. The practice of watering in the morning on bright days makes it easier to control damp conditions at night with heat and ventilation. The greenhouse air at night is more apt to become saturated with moisture and the plants covered with "sweat" if the watering is done late in the day. Mulches of straw or manure on the beds absorb and hold water. Their use emphasizes even more the importance of morning watering and ventilation.

Excessive applications of water and afternoon watering on warm bright days cause the release of water from the leaves and stems, especially if the air in the night following is cool and moist (Fig. 4). Transpiration is suddenly checked while the absorption of water through the roots continues. The exudation of water or guttation creates moisture conditions on the foliage favorable for disease. These drops or beads of water become larger and finally run or drop off the plants. If the watering is moderate in amount and is done in the morning in bright weather and if ventilation is continued at night, guttation can be avoided.

Disregard of these simple rules governing the watering of greenhouse tomatoes can be an important factor contributing to the incidence and progress of tomato leaf mold.

TEMPERATURE AND HUMIDITY CONSIDERATIONS

The management of the greenhouse air to prevent atmospheric conditions favorable to the prevalence of tomato leaf mold is by no means simple. It may contribute to the success of other worthy control measures, or it may undo all of the good accruing from them.

Small (42, 45) emphasized the importance of keeping the relative humidity of the greenhouse air below 75 percent, but this is impossible in greenhouses of any design in Massachusetts. Rippel (40) found that a relative humidity below 85 per cent for 18 to 20 hours each day is not impossible in greenhouses in Germany and this, according to his studies, is necessary to prevent infection. Abnormal atmospheres in the greenhouse are the result of inefficient ventilating and inadequate ventilating area. Both, therefore, are vitally concerned in the problem of controlling tomato leaf mold.

Spore germination occurs in relative humidities above 95 percent and is best at 100 percent or air saturation and in water; and these conditions often occur on the leaf surface and in the immediate atmosphere of the foliage when lower relative humidities exist in the open greenhouse atmosphere. The more humid conditions on the leaf are the result of transpiration and guttation from the foliage and moisture condensation (dew) from the air. A temperature range of 75° to 80° F. is optimum for spore germination and infection, and it is also about the ideal day temperature range for growing tomatoes under glass.

Air circulation is very important in the correction of excessive temperature and moisture conditions. If the ventilators admit insufficient air, opening of doors and construction of additional ventilators in stagnant corners and in the ends of the greenhouse are desirable. Ventilation must be increased with increased heat from the sun. Late in the spring the maximum amount of ventilation may be provided day and night. At this season and in the early fall, when the outside temperatures on occasional nights drop to 50° F., a minimum heating temperature of 60° to 65° F. and ventilation seems best and some ventilation may be necessary from both the sides and the spans of the greenhouse. The ventilators should be lowered but not closed at sundown after the heat is in the pipes. This practice will prevent a sudden rise in the relative humidity of the air.

The appearance of dew or "sweat" on the plants in the morning is rather common in the off-heating season. This happens when the greenhouse is closed at night and the warm confined air is gradually cooled, and can be avoided by ventilation or, if there is a considerable temperature decline, by heat and ventilation. In the fall an inside minimum temperature of 60° to 65° F. with ventilation is often definitely necessary to prevent high relative humidities. This can be appreciated by a study of hygrothermographic records for August, September, and other off-heating periods, of which Figure 5 is typical. The records show that moisture saturation and minimum temperatures of 55° to 60° F. occur at night and high temperatures and low relative humidity in the daytime. The effect of heating on the relative humidity of the air at night is quite insignificant at this season because of the very narrow difference existing at night between the inside and outside temperatures unless the temperatures are raised above 60° F. When the outside night temperatures drop to 50° F. and below, as they do in October and later months, the effect of heat or an inside minimum temperature of 60° F. on lowering the humidity of the air may be considerable, as is indicated by Figure 5B.

In the morning a gradual warming of the greenhouse air above the prevailing night temperature is desirable. This is accomplished by gradually increasing the ventilation as the sun increases in power. In constrast, a sudden cooling of the air at this time may cause a heavy deposit of dew which may remain for some time even after the temperature rises.

Wilson and Alexander (55) and Alexander (5) reported less leaf mold in Ohio greenhouses when heating with ventilation was practiced after June 25. Alexander implied the need of heat as late in the summer as tomatoes are picked and as early as September 1 in the fall season. Walker and Sumner (53) reported less leaf mold in Wisconsin greenhouses when heating began in August. Heating up to late June and as early as the first of September is uncommon in Massachusetts, but where it is practiced, development of the disease is delayed. With coal at nearly $7 per ton delivered, and the average price of tomatoes much less than in pre-depression years, late and early heating obviously absorbs a good share of the profits; and therefore, it has not become a generally accepted practice in Massachusetts.

In spite of diligent management the amount of control of the disease can be entirely out of proportion to the added effort and costs, especially when other contributory control measures are disregarded. The sometimes epidemic occurrence of the disease where late and early heating are practiced is evidence of this fact. Once the disease becomes general on the lower leaves early in the growing period, attempts to check it with heat and ventilation are usually ineffective. For delaying the appearance of the disease or retarding the progress of infection, the practice of ventilating freely from May to October, day and night, and using heat to maintain minimum temperatures between 60° and 65° F. would seem to be ideal. These minimum temperatures are also necessary to promote the steady ripening of the fruit.

EXPERIMENTS IN CONTROL

Hand Management and Minimum Temperature Control

The foregoing information relative to culture and house management was the basis of control demonstrations carried on for several seasons at the Waltham Field Station. Practices recognized as unfavorable to the disease were compared with practices more or less inconsistent with good management and culture. The growing areas were 32 x 32 feet, in different sections of the same greenhouse and separated from each other by glass partitions. The conditions were like those in two adjacent commercial greenhouses except that the temperatures were regulated by thermostats and not by hand-controlled valves. Under poor management, warm, stagnant, moist atmospheres were encouraged by neglect of ventilation and proper methods of watering. Where good management was practiced, efforts were made to keep the relative humidity of the greenhouse air as low as possible with a minimum temperature bordering 60° F., and not to permit temperatures above 70° F. from late April to mid-November without some ventilation. Efforts to prevent high relative humidities at night without heat were not generally successful in the early fall and at other critical times, as is evident from a study of the hygrothermographic records in the greenhouse for September, October, and November, as shown in Figure 5A. A comparison of Figures 5A and 5B reveals the influence of boiler heat on relative humidity, but this is usually of small significance in the months from September to November when the outside and inside minimum temperatures parallel each other closely. As the outside temperatures become colder and diverge further from the inside minimum temperature of 60° F., the influence of boiler heat on the relative humidity becomes more marked (Fig. 5B) and the development of the disease is retarded.

The effect of the two methods of management on the control of the disease was determined by a tabulation of healthy and infected leaflets at each pruning. In the fall growing season (1926) 30 percent of the leaflets were infected with leaf mold under poor management and 33 percent under good management (Table 2). The disease was not important enough to influence the yield. In the spring cropping season (1927) 76 percent of the leaflets showed leaf mold under poor management and 19 percent under good management (Table 3). In this season the average yield per plant under good management was 9.24 pounds, of which 8.64 pounds were classed as first grade fruit, in comparison with 8.67 pounds obtained under poor management, of which 7.85 pounds were fruit of first grade. In the fall cropping season (1927) there was no contrast in the amount of disease. It was bad in both houses and there was no heat to permit good management during the early critical period, because of the installation of new boilers.

TABLE 2.—CONTROL OF TOMATO LEAF MOLD BY GREENHOUSE MANAGEMENT
Fall Cropping Season 1926.

Date of Foliage Counts	Percentage of Diseased Leaflets	
	With Poor Management	With Good Management
September 20, 1926	35	9
October 1, 1926	6	2
October 6, 1926	8	23
December 20, 1926	35	75
January 11, 1927	84	56
January 29, 1927	27	28
Total	30	33

TABLE 3.—CONTROL OF TOMATO LEAF MOLD BY GREENHOUSE MANAGEMENT
Spring Cropping Season 1927.

Date of Foliage Counts	Percentage of Diseased Leaflets	
	With Poor Management	With Good Management
June 16, 1927	56	0.1
July 12, 1927	98	14.0
July 31, 1927	100	32.0
Total	76	19.0

TABLE 4.—CONTROL OF TOMATO LEAF MOLD BY GREENHOUSE MANAGEMENT
Spring Cropping Season 1928.

Date of Foliage Counts	Percentage of Diseased Leaflets	
	With Poor Management	With Good Management
April 4, 1928	0.0	0.0
April 16, 1928	5.06	0.16
May 7, 1928	34.69	0.55
May 18, 1928	75.0	1.02
June 12, 1928	100.0	3.00
June 28, 1928	100.0	3.56
July 17, 1928	100.0	6.65
Total	45.09	2.08

TABLE 5.—RELATION OF LEAF-MOLD CONTROL TO YIELD AND VALUE OF TOMATOES

Spring Cropping Season 1928.

	With Poor Management	With Good Management
Average yield per plant:		
Firsts . . . . . pounds	5.17	7.99
Seconds . . . . . pounds	2.55	2.56
Total . . . . . pounds	7.72	10.55
Average value per plant:		
Firsts	$1.53	$2.36
Seconds	.30	.32
Total	1.87	2.68
On ¼-acre basis:		
Total yield . . . . . pounds	15,980.4	21,838.5
Total value	$3,870.90	$5,547.60

In the spring growing season (1928), 45 percent of the leaflets were infected with leaf mold under poor management and only 2 percent under good management (Table 4). This control meant a significant average increase per plant of 2.83 pounds and 81 cents, or 5,858 pounds and $1,677 on a quarter-acre basis (Table 5).

In the fall season (1928) 85.6 percent of the leaflets showed leaf mold under poor management and 14.5 percent under good management (Table 6); but the difference in yield was only .79 pounds and 20 cents per plant, or 1,635 pounds and $414 on a quarter-acre basis (Table 7). The small difference in yield with a significant contrast in disease conditions showed that there were other factors limiting yield. It is also apparent that considerable foliage loss from the disease is necessary before there is any loss in yield. While the value from good management practices alone was not always striking, nevertheless in general the results show justification for the effort.

TABLE 6.—CONTROL OF TOMATO LEAF MOLD BY GREENHOUSE MANAGEMENT

Fall Cropping Season 1928.

Date of Foliage Counts	Percentage of Diseased Leaflets	
	With Poor Management	With Good Management
September 11, 1928	0.0	0.0
September 25, 1928	4.1	8.1
October 26, 1928	90.6	36.8
November 22, 1928	100.0	22.5
December 22, 1928	100.0	10.5
January 10, 1929	100.0	8.1
January 30, 1929	100.0	13.3
Total	85.6	14.5

TABLE 7.—RELATION OF LEAF-MOLD CONTROL TO YIELD AND VALUE OF TOMATOES

Fall Cropping Season 1928.

	With Poor Management	With Good Management
Average yield per plant:		
Firsts........................pounds	2.79	3.59
Seconds........................pounds	1.56	1.55
Total........................pounds	4.35	5.14
Average value per plant:		
Firsts........................	$0.66	$0.86
Seconds........................	.18	.18
Total........................	.84	1.04
On ¼-acre basis:		
Total yield....................pounds	9,004.5	10,639.8
Total value........................	$1,738.80	$2,152.80

Forced Air Ventilation and Humidity Control

By the simple method of introducing outside air over a heater, Stair et al. (48) completely prevented tomato leaf mold from developing on plants in the hotbed. Wilson (56) noted that with forced air no periods occurred up to May 14 when the relative humidity was 86 percent for 10 hours or more, while naturally ventilated houses showed at least 35 such periods. For the first monthly periods in the spring, the average relative humidity in a naturally ventilated house was 77.7, 77.8, and 82.5 percent in contrast to 61.5, 67.5, and 72.1 percent in a forced-air-ventilated house. The possibility of controlling the disease by combining forced air with natural ventilation was suggested from these readings. The admission of the inconsistency and unreliability of hand control of ventilation and heating in commercial practice stimulated the commercialization of costly automatic systems of greenhouse air conditioning. The Zephyrator (1, 2, 3, 27, 28, 29), reported to have been installed in several ranges in Ohio, relied upon an electrically driven centrifugal blower to force air through underground pipes and overhead ducts into the greenhouse, the purpose being to increase the evaporating power of the air by stirring it. Evaporation was doubled without appreciable draft (Newhall 29) when air was stirred at the rate of 44 feet per minute and in a range of 1½ acres the air was changed theoretically in 22 to 30 minutes. Parker (32) asserted that air must move at the rate of 2 feet per second to prevent atmospheric stagnation and at this velocity there is a complete change of air without drafts. Newhall (30) described an installation in which the blower is placed in front of a series of radiators which may be fed with either steam or cold water so that the greenhouse air may be warmed or cooled.

Another system (4) first compressed the air to a fraction of its volume then introduced it into the greenhouse through a series of perforated pipes, similar to an overhead sprinkler system which could be adjusted for any desired angle and volume. The compression of the air greatly increased its capacity to absorb water.

Guba (18) described a system of relative humidity control and forced ventilation relying on the variation of the greenhouse temperatures between a fixed minimum and maximum and by the starting and stopping of exhaust fans. This is brought about by a hygrostat which shifts from a low to a high thermostat and which may be set at any desired temperature range. By increasing the temperature when the relative humidity rises, the humidity will tend to be lowered in a definite ratio for each degree rise in temperature. The starting of exhaust fans simultaneously with the introduction of pipe heat stirs the air and causes the infiltration of outside cooler air. This system insures considerable accuracy since it relies upon the sensitivity of thermostats and hygrostats. There is no draft of air or inside construction to make shadows or take up growing space as in the Ohio installations. This system of humidity control and forced ventilation was compared with a fixed thermostatic minimum temperature control and hand ventilation in two separates houses designated A and B.

The minimum temperature in greenhouse B was adjusted for 60° F. (temperature control) and Figure 5B shows the influence of such a prevailing minimum temperature upon the course of the relative humidity of the greenhouse air in the colder months of the year. In greenhouse A, air control instruments were gauged for relative humidities below 85 percent (humidity control), which was not always possible within a temperature range of 60° to 75° F., representing the extreme adjustment for the low and high thermostats. This was especially true during September, October, and critical periods in November. With the advance of the season and the decline of the outside mean minimum temperature, the maintenance of relative humidity below 80 percent within a fluctuating temperature range of 60° to 70° F. was more readily accomplished. In April to June, conditions again are like those in the early autumn months.

Less attention to ventilation was necessary in greenhouse A provided with air-conditioning equipment than in greenhouse B with thermostatic minimum temperature control only. In the former, the ventilators were opened when the temperature reached 72° to 75° F.; in the latter, ventilation was much more freely applied, but the conditions were not as accurately controlled.

The results under the two conditions of air control in the fall of 1929 (Table 8) showed a difference of 17.6 in percentage of infected leaflets, the greater amount

TABLE 8.—RELATION OF AUTOMATIC HUMIDITY REGULATION AND AUTOMATIC TEMPERATURE REGULATION TO THE CONTROL OF TOMATO LEAF MOLD

Fall Cropping Season 1929.

Date of Foliage Counts	Percentage of Diseased Leaflets	
	House A Humidity Control	House B Temperature Control
August 21, 1929	0.0	0.0
September 24, 1929	15.4	16.8
October 31, 1929	84.4	93.1
November 27, 1929	49.5	99.0
January 2, 1930	17.4	57.9
January 15, 1930	20.1	23.4
Total	33.2	50.8

of disease being present where humidity conditions were rather indifferently regulated and where the minimum temperature bordered 60° F.

The same comparisons were made in the fall cropping season of 1930. There were 28.7 percent more infected leaflets in greenhouse B where a fixed minimum temperature of 60° F. maintained only a limited control of the relative humidity than in greenhouse A where a fluctuating automatically controlled temperature and forced ventilation operated fairly well to keep the relative humidity under 85 percent (Table 9).

TABLE 9.—RELATION OF AUTOMATIC HUMIDITY REGULATION AND AUTOMATIC TEMPERATURE REGULATION TO THE CONTROL OF TOMATO LEAF MOLD

Fall Cropping Season 1930.

Date of Foliage Counts	Percentage of Diseased Leaflets	
	House A Humidity Control	House B Temperature Control
October 17, 1930	19.7	21.9
November 21, 1930	25.4	41.2
December 26, 1930	18.2	35.7
January 26, 1931	10.3	63.3
Total	18.2	46.9

The average yield in pounds per plant in each greenhouse was:

Grade of Tomatoes		Greenhouse A	Greenhouse B
No. 1	pounds	2.32	2.9
No. 2	pounds	1.00	1.3
No. 3	pounds	.37	.5
Total		3.69	4.7

The higher yield did not coincide with better control of the disease, which suggests the operation of other limiting factors. Obviously, the fuel cost of regulating the conditions in greenhouse A was greater than in greenhouse B.

Further comparisons were made in the spring cropping season of 1931. The disease was equally bad in both greenhouses. After May 15 all the ventilators were kept open day and night; nevertheless, the disease, which had already appeared, eventually spread to all of the foliage. The yield and quality of the tomatoes did not appear to be seriously affected. Where the humidity was kept fairly well below 85 percent within a temperature range of 60° to 75° F., the yields averaged 10.28 pounds per plant, of which 7.35 pounds were of first grade, in contrast to a total of 11.92 pounds of which 8.63 pounds were of first grade, under a minimum temperature of 60° F. and natural ventilation. The yields were considered exceptionally good, but relative humidity below 85 percent with temperatures between 60° and 75° F. again showed an adverse influence on yield.

A further comparison of the two sets of conditions was made in the fall of 1931. A difference of only 10.1 in percentage of infected leaflets could be shown (Table 10) in favor of automatic humidity control and forced air.

Table 10.—Relation of Automatic Humidity Regulation and Automatic Temperature Regulation to the Control of Tomato Leaf Mold

Fall Cropping Season 1931.

Date of Foliage Counts	Percentage of Diseased Leaflets	
	House A Humidity Control	House B Temperature Control
October 29, 1931	78.2	77.1
December 2, 1931	75.4	66.7
January 4, 1932	80.8	94.6
January 13, 1932	47.0	85.3
Total	69.0	78.9

In general, the benefit from control measures in these experiments was too insignificant to justify the installation of costly air-conditioning apparatus. The conditions imposed always gave a lower yield. The commercialization of greenhouse air control systems seems to have been too sudden and speculative. Installations involving the forced introduction of outside air and its distribution throughout the growing area through a piping system proved a fallacy. The conveniences of minimum thermostatic temperature control over hand-valve control in greenhouse heating are recognized and several such installations are in use in Massachusetts. The cost of further controlled air conditioning is at present prohibitive and unjustified in commercial practice.

GREENHOUSE DESIGN AND LOCATION

Greenhouse design and location are closely bound up with the problem of disease control. Both govern the means for providing adequate ventilation and air circulation. It has been noted in Ohio (5, 55) that north and south houses with ridge-hinged ventilation have less leaf mold. Multiple houses in a continuous series are objectionable. This type of range is considered more desirable from the viewpoint of ventilation if built in sections of three houses each with side ventilators and the sections connected by a covered alley (5). Judging from experience in Massachusetts, single houses without the connecting covered alley are more acceptable (Fig. 6 A, B). The alley does not permit good air movement about each individual house.

The need for adequate ventilating area in greenhouse design is generally recognized (33, 47). The modern high-ridged, even-span-roofed house all of glass with continuous ventilation on sides, ends, and spans offers a remarkable contrast to the low-span-roofed house with its row of single-pane ridge-hinged ventilators and its back or north side of wood. The earliest construction showed a strong disregard for light and normal atmospheres (Fig. 6 C, D). It has been stated that the best type of greenhouse for tomato culture is one which permits the removal of the greenhouse roof in the summer (15). The improvement in the provision for light and air shown in the evolution of greenhouse design suggests an approach to this end (Fig. 7 A). The inadequacy of ventilating area is still an evil of much of the recent greenhouse construction for tomato culture, and reveals the desirability of closer cooperation between plant pathologists and greenhouse construction companies. There would seem to be no justification in these times for construction with inadequate ventilating area, particularly for tomato culture.

Proper elevation and exposure contribute to successful ventilation. Situations sheltered by trees and shrubs and buildings, or by surrounding elevations of land are objectionable. The planting of trees and shrubs close to the greenhouse for landscape effect is also objectionable. These conditions obstruct light and air and tend to offset the advantages which desirable greenhouse design can contribute toward efforts to control disease (Fig. 7 B, C).

PROTECTION WITH FUNGICIDES

Ordinary preparations of sulfur and copper are of little if any value in controlling tomato leaf mold in the greenhouse (17). The vaporization of sulfur combined with sound cultural and management practices is considered the best method of control (8, 17). The merit of vaporized sulfur has been substantiated by scientific reports and growers' experiences. Temperatures around 70° F. combined with bright sun contribute to the volatilization and toxicity of vaporized sulfur. The treatments should begin in April before the disease appears and be continued at about 10-day intervals until the latter part of June. For the fall planting the treatments should be given before the plants are set out and be repeated at 7 to 10 day intervals until early November. The rate of application cannot be computed in any definite ratio but must be judged by the density of the vapors in the greenhouse air. Excessive charges are not injurious except that they are apt to produce a perceptible residue on the fruit which is difficult to remove.

In practice there has been an evolution of devices for generating and applying vaporized sulfur from a simple assemblage of stove and dish to apparatus of more practical and safer operation attached to the exhaust of an automobile engine and capable of charging large greenhouses in a short space of time.

The sulfuring of the hot steam pipes is not comparable in substance or effect to the superheating and vaporization of sulfur over a heating unit. Sulfur is not vaporized until it reaches its melting point and this requires a steam boiler pressure of around 20 pounds. The usual steam-pipe temperatures merely warm the sulfur and cause it to fume, this being identical with the fuming of the sulfur deposit on the leaf surface under conditions of sunlight and warm house temperatures. Even with a pipe temperature high enough to melt the sulfur, only a small amount is vaporized and most of it runs off and is lost. The practice requires considerable nightly confinement of the greenhouse air and this encourages the progress of the disease. Moreover, protection is most necessary during the off-heating season when ideal conditions for the disease exist. It is much more desirable to use a special portable apparatus for vaporizing sulfur which can be operated independently of the heating system.

Bewley and Orchard (9, 10) successfully controlled tomato leaf mold with a spray consisting of 1/8 ounce of salicylanilide paste (Shirlan H. B.[2]) and ¼ ounce of sulfonated oil spreader (Agral 1[2]) or 1/8 ounce Agral N[2] (36) in one gallon of water. The merit of the spray for this purpose has been generally confirmed (6, 11, 17, 22, 47). The spray does not leave a residue but it cannot safely be used when oil emulsion is used for red spider mite unless 10 days elapse between the two applications. Copper oxychloride suspension (17 percent copper) has also been reported as being effective, but marks the fruit badly. Petroleum oil emulsion and ½ fluid ounce of copper oxychloride per gallon are compatible and nonstaining and are recommended in England when both red spider and leaf mold are present (31, 36).

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[2] Manufactured by the Imperial Chemical Industries, Ltd., Millbank, London, England.

Rippel (38, 39) asserted that the spores of the fungus possess extraordinary resistance to the action of chemicals and require concentrations in excess of the tolerance of the host to obtain control of the disease. It is asserted that a large portion of the soluble poison is absorbed by the thick wall of the spore leaving none to affect the plasm. Guba (17) demonstrated the toxicity of several chemicals to the spores of the tomato leaf mold fungus and indicated the limitations to their merit in greenhouse culture. The practical difficulty of obtaining adequate protection of the lower surfaces of the leaves where infection occurs and the inertness to the fungus of dry chemical residues on the leaves under conditions which otherwise favor spore germination are offered as fundamental reasons for the inability to control the disease with ordinary spraying and dusting materials in greenhouse culture. The necessity of frequent treatments during the critical season and of using fungicides which are both inert to the plant and nonstaining also impose serious limitations to the use of spraying and dusting materials for combating the disease. Many reports show the value of Bordeaux (17) under field growing conditions. The assertion that effective fungicides for controlling leaf mold are lacking is inconsistent with the evidence (6, 9, 10, 11, 17, 19, 24, 41, 46, 47).

ERADICATION OF THE FUNGUS BETWEEN PLANTINGS

The disinfestation of the greenhouse interior to destroy fungous and insect pests existing outside of the soil is an important sanitary practice which obviously should contribute to the control of tomato leaf mold during the succeeding planting. Some disinfestation of the greenhouse interior after cleaning out the vines may be accomplished by treating the soil with chemicals and confining the gases for two or three days after the soil treatment. However, the destruction of pests before cleaning out the finished vines which harbor them is preferable to prevent a reinfestation from the discarded plant material outside. Several chemicals have been used for this purpose but burning sulfur fumigation has received most recognition because it is economical, practical, and lethal to both insects and fungi.

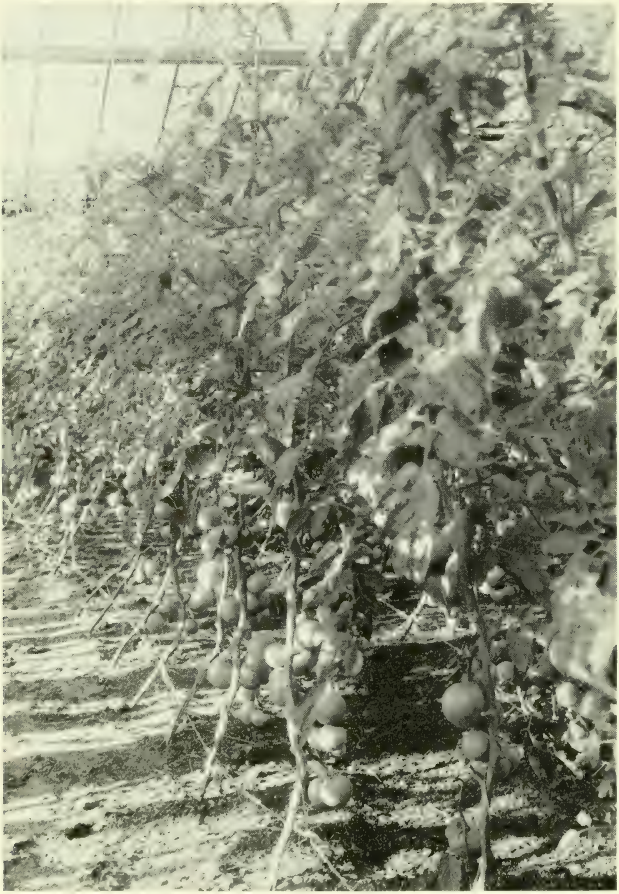

Figure 1. A planting of tomatoes in October pruned to admit light and undercurrents of air.

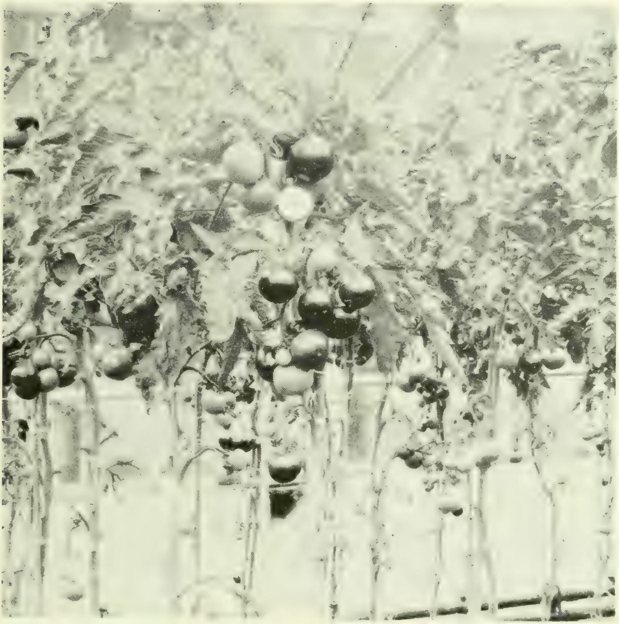

Figure 2. A planting of tomatoes in July showing the ultimate condition of the plants as the result of the progressive pruning of the foliage below the trusses of matured and harvested fruit. Pruning aids in the eradication of leaf mold and the circulation of air necessary to control relative humidity.

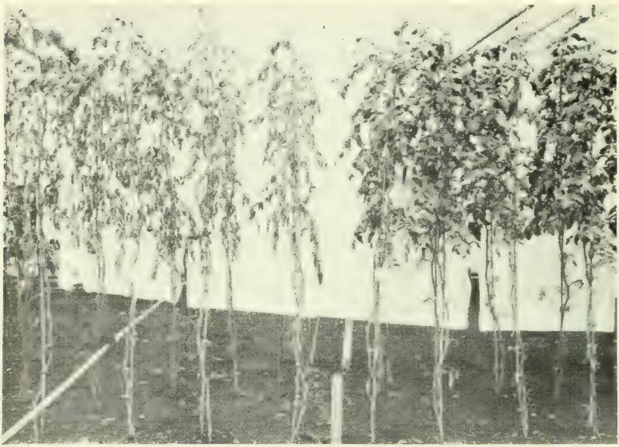

Figure 3. Comparison of overhead and bottom watering in relation to the prevalence of tomato leaf mold. Irrigation pipe and more severely diseased foliage on the left, the result of overhead watering.

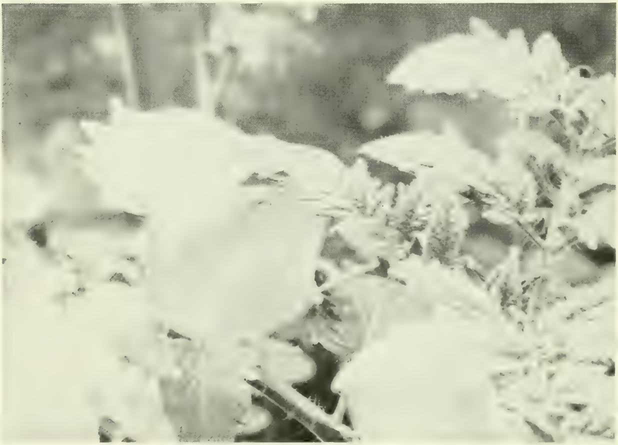

Figure 4. Guttation and dew on the foliage are favorable to tomato leaf mold.

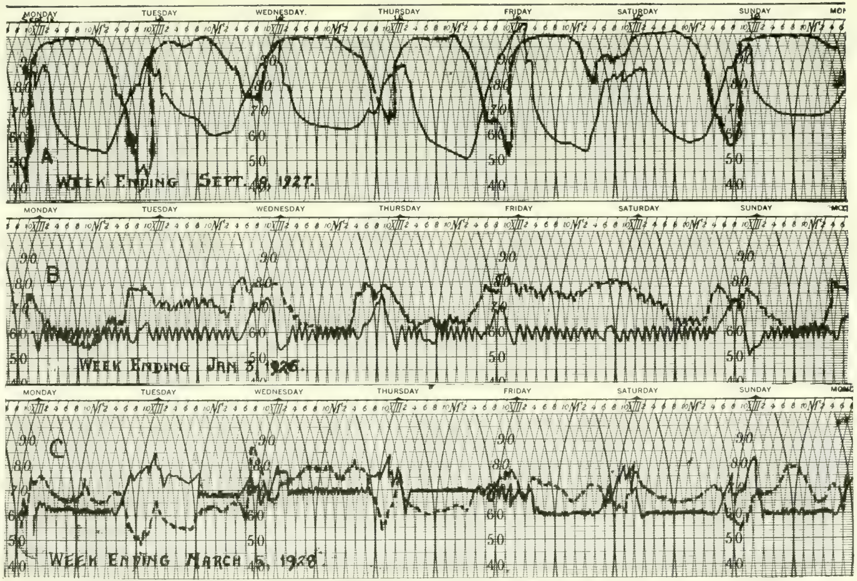

Figure 5. Hygrothermographic records in the greenhouse in tomato culture, showing (A) course of relative humidity and temperature typical of greenhouse atmospheres during the off-heating season; (B) in contrast, the influence of a minimum mean growing temperature of 60° F. on the relative humidity of the greenhouse air; and (C) course of temperature automatically fluctuated between extremes of 60° and 75° F. to maintain relative humidity values below 85 percent. (The solid line represents temperature; the broken line, relative humidity.)

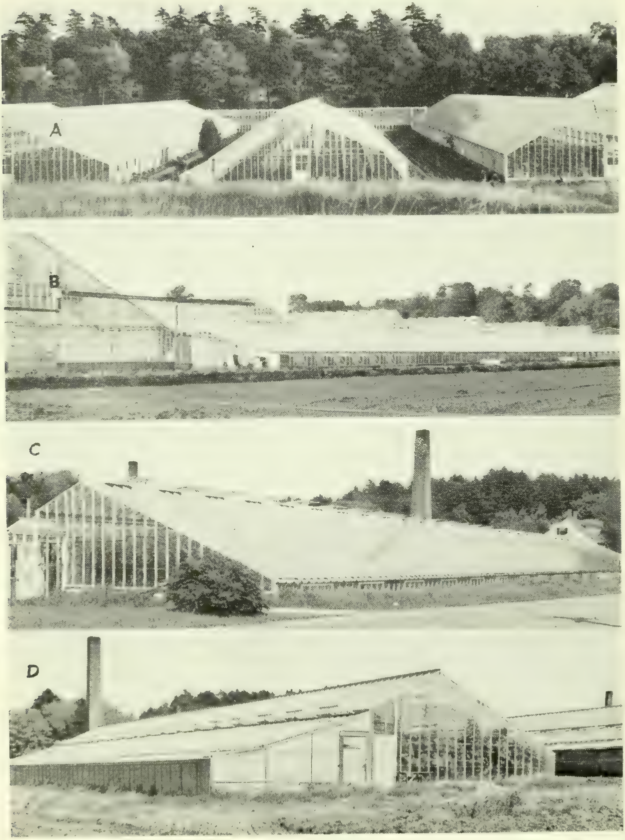

Figure 6. A, B. Greenhouse range showing obstruction to air circulation about the ends of individual houses by a connecting lean-to house. C, D. Low lean-to houses showing a lack of regard for light and ventilating area which makes proper air control very difficult.

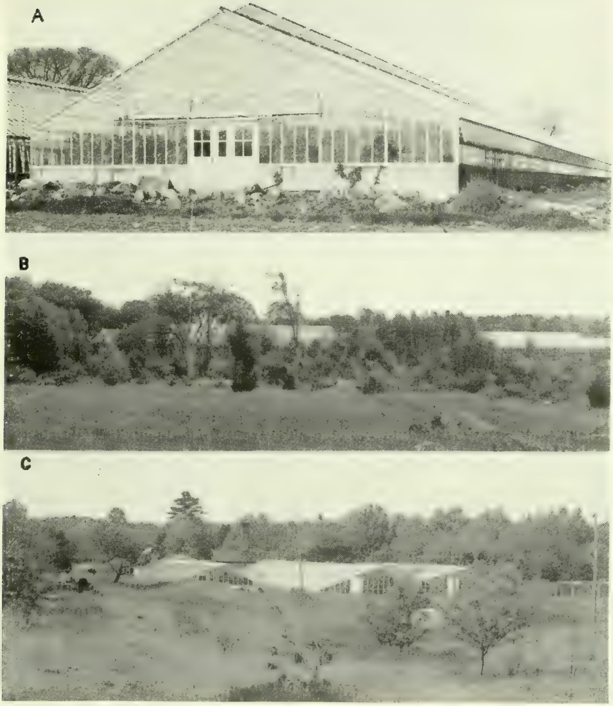

Figure 7. A. One of a series of disconnected greenhouses embodying a significant regard for adequate ventilating area, light, and air circulation about each house for controlling tomato leaf mold. All sides and spans are provided with ventilators. B, C. Greenhouse ranges badly situated with respect to exposure to sunlight and atmospheric drainage.

Fumigation with Burning Sulfur

Past recommendations show a lack of uniformity in dosage recommendations for burning sulfur between crops in greenhouses. Most of the recommendations are based on the dosage necessary to accomplish destruction of the red spider mite (Table 11).

TABLE 11.—QUANTITY OF SULFUR TO 1,000 CUBIC FEET RECOMMENDED FOR BURNING IN THE DISINFESTATION OF GREENHOUSES

Authority	Quantity	Period	Remarks
Makemson (26)	5 pounds	24 hours	
Williams (54)	2 pounds		1 percent concentration of SO_2
Small (44, 46)	1 pound		Distributed in 5 heaps
Van der Meer (52)	10 ounces	2 hours	In commercial practice
Van der Meer (52)	2½ ounces	½ hour	In laboratory chamber
Read (36)	1 pound		
Haseman and Jones (20)	30 pounds		For greenhouse pests in general
Compton (12)	3-5 pounds		For greenhouse insects

Small (43, 44, 46) noted that several heaps of burning sulfur gave better results than the same quantity of sulfur in one heap, and that rapid generation of the gas was essential to an effective destruction of the spores of the tomato leaf mold fungus. Judging from recommendations in popular articles, the ratio of 1 pound of sulfur to 1,000 cubic feet of greenhouse space has received most general acceptance. It is generally conceded that, even at this dosage, some eggs and mites survive. This fact has led to the practice of burning even greater amounts of sulfur to 1,000 cubic feet.

The burning of excessive quantities of sulfur in greenhouses between plantings is harmful to iron frames and piping, wires, metal gutters, and paint. The film of acid formed on the interior surfaces softens the paint and causes it to shed. The soluble residues gathering in water and subsequently dripping upon the plants in the beds have been the cause of much plant injury. These effects from the burning of sulfur have been the chief factor in discouraging the practice for cleaning up pests between plantings.

Read and Orchard (35) and Read (36) found that zinc sulfate was formed from the action of sulfuric acid on white zinc paints and galvanized wire, and that 1 pound of sulfur to 1,000 cubic feet resulted in considerable drip damage. No damage resulted where surfaces were protected with lead or barium base paints. More recently Kadow et al. (25) reported an instance of injury to tomatoes from drip from zinc galvanized pipes and wires in a greenhouse where sulfur had been burned as a clean-up measure, but the exact dosage was not stated. In Massachusetts greenhouses injuries to plants from drippings from iron pipes, zinc-coated wires and metal, and from surfaces covered with zinc paints following the burning of large amounts of sulfur have been frequent. A study of the problem, therefore, seemed desirable.

Reaction with Paint

Various paint pigments[3] were added to water and painted on panes of glass. After drying, these pigments were exposed in a large chamber to burning sulfur fumigation and 5 percent suspensions of the residues in distilled water were made. The filtrates were tested for pH values and then sprayed on delphinium and tomato plants for toxicity manifestations. The results were recorded three to five days after spraying (Table 12). Injury of varying degree occurred. The greatest injury resulted from zinc oxide and leaded zinc. Basic lead carbonate and aluminum powder did not cause injury. No definite correlation was shown between the pH value of the extract and its toxicity to plant foliage. Some of the pigments showed a marked hydrolysis after fumigation, expressed in the strongly acid character of the filtrates, i. e. titanium dioxide, Titanox B, Lithopone, and zinc sulfide; and extracts of these pigments caused some injury in one or another of the experiments. Extracts of pigments not exposed to burning sulfur fumigation were not toxic.

TABLE 12.—EFFECT OF EXPOSURE OF PAINT PIGMENTS ON GLASS PANES TO FUMIGATION WITH BURNING SULFUR, AND THE ACTION OF EXTRACTS OF THE RESIDUE ON PLANT FOLIAGE

Paint Pigment	pH of Paint Pigment		Degree of Injury from Extract	
	Before SO_2 Fumigation	After SO_2 Fumigation	Delphinium	Tomato
Basic Lead Carbonate	6.6–6.8	6.4-6.6	None	None
Lead Sulfate	6.2–6.4	6.3–6.4	Slight	Slight
Titanium Dioxide	6.6–6.8	3.0 or less	Slight	None
Titanox B	6.8–7.0	3.0 or less	None	None
(Titanium Dioxide....25%)				
(Barium Sulfate.......75%)				
Zinc Oxide	6.6–6.8	6.4–6.6	Severe	Severe
Leaded Zinc	6.6–6.8	6.4–6.6	Severe	Severe
(Zinc Oxide...........65%)				
(Lead Sulfate.........35%)				
Zinc Sulfide	7.0–7.2	4.4–4.6	None	Slight
Lithopone	7.0–7.2	4.3–4.5	None	Slight
(Zinc Sulfide..........28%)				
(Barium Sulfate.......72%)				
Aluminum Powder		4.6	None	None

These same white pigments were moistened in Petri dishes and exposed to an atmosphere of burning sulfur. They were then dried and washed and the amount of water-soluble material in each determined (Table 13). Basic lead carbonate, which did not cause injury in any of the experiments, showed the least water-soluble material. Zinc oxide and leaded zinc, which caused the greatest injury, also yielded the most water-soluble material. In other instances injury, if any, was slight and the amount of water-soluble material was likewise small in proportion. The zinc oxide pigments Nos. 2 and 412 were rendered appreciably soluble.

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[3] Paint pigments supplied through the courtesy of Sherwin-Williams Company, Cleveland, Ohio.

TABLE 13.—AMOUNT OF WATER SOLUBLE SALT RESULTING FROM EXPOSURE OF WHITE PAINT PIGMENTS ON GLASS TO FUMIGATION WITH BURNING SULFUR

Paint Pigment	Stock Number (Sherwin-Williams Company)	Pigment Recovered Grams	Water Soluble Salt	
			Grams	Percent
Basic Lead Carbonate	18	3.63	0.03	0.83
Lead sulfate	9	3.11	0.11	3.54
Titanium Dioxide	1403K	2.65	0.07	2.64
Titanox B	1097	1.78	0.03	1.69
(Titanium Dioxide....25%)				
(Barium Sulfate.......75%)				
Zinc Oxide	2	6.97	2.95	42.32
Leaded Zinc	412	3.82	1.21	31.68
(Zinc Oxide...........65%)				
(Lead Sulfate.........35%)				
Zinc Sulfide	1538	2.56	0.09	3.52
Lithopone	416C	2.42	0.11	4.55
(Zinc Sulfide..........28%)				
(Barium Sulfate.......72%)				

TABLE 14.—EFFECT OF EXPOSURE OF PAINT PIGMENTS IN OIL ON WOOD TO FUMIGATION WITH BURNING SULFUR, AND THE ACTION OF EXTRACTS OF THE RESIDUE ON PLANT FOLIAGE

Paint Pigment	pH of Extract	Degree of Injury from Extract	
		Lettuce	Tomato
Basic Lead Carbonate (18)	4.2–4.4	None	None
Lead Sulfate (9)	4.8–5.0	Slight	Slight
Titanium Dioxide (1403K)	3.0 or less	Slight	Slight
Titanox B (1097)	3.0 or less	None	Trace
(Titanium Dioxide....25%)			
(Barium Sulfate.......75%)			
Zinc Oxide (2)	6.2–6.4	Severe	Severe
Leaded Zinc (412)	6.2–6.4	Severe	Severe
(Zinc Oxide...........65%)			
(Lead Sulfate.........35%)			
Zinc Sulfide (1538)	3.3–3.5	None	None
Lithopone (461C)	3.3–3.5	Slight	Slight
(Zinc Sulfide..........28%)			
(Barium Sulfate.......72%)			
Powdered Aluminum	4.6	None	None
Aluminum Paint Mixture	4.6–4.8	Slight	None

In a further experiment the various paint pigments were mixed with linseed oil and painted on wood. After drying, the painted boards were exposed in a humid chamber to fumigation with burning sulfur. After fumigation, the paint coatings were removed and added to water to make a 10 percent extract. The extracts were tested for pH values and atomized on foliage of tomato and lettuce for an index of their toxicity (Table 14). The results confirm the fact that zinc oxide in paint on interior greenhouse surfaces can be a major cause of drip injury following fumigation with burning sulfur.

TABLE 15.—AMOUNT OF WATER SOLUBLE ZINC IN RESIDUES RESULTING FROM EXPOSURE OF ZINC WHITE PAINTS TO FUMIGATION WITH BURNING SULFUR AND THE ACTION OF EXTRACTS OF THE RESIDUES ON LETTUCE AND TOMATO FOLIAGE

Composition of Paint*		Degree of Injury from Extract		Water Soluble Zinc in 5 cc. of Extract	
		Lettuce	Tomato	Zinc Grams	Zinc as Zinc Sulfate Grams
Zinc Oxide and Asbestine					
25%	75%	Trace	Severe	0.0528	0.2322
50%	50%	Moderate	Severe	.0643	.2827
75%	25%	Severe	Severe	.0572	.2515
Leaded Zinc and Asbestine					
25%	75%	None	Severe	.0314	.1381
50%	50%	Slight	Severe	.0478	.2102
75%	25%	Severe	Severe	.0460	.2023
Zinc Oxide and Basic Lead Carbonate					
25%	75%	Slight	Severe	.0298	.1310
50%	50%	Severe	Severe	.0338	.1486
70%	30%	Slight	Severe	.0387	.1702
90%	10%	Slight	Slight	.0125†	.0549
Zinc Oxide and Titanium Dioxide					
25%	75%	Severe	Severe	.0541	.2379
50%	50%	Severe	Severe	.0727	.3197
70%	30%	Slight	Severe	.0494	.2172
90%	10%	Slight	Severe	.0316	.1389

*Asbestine=Magnesium silicate, calcium carbonate not more than 4%.
Leaded Zinc=Zinc oxide 65%, lead sulfate 35%.

†1 cc. sample.

A further comparative test was made of several prepared paints[4] containing different ratios of zinc oxide. The paints were applied to panels of wood, allowed to air dry, and then exposed to fumigation of burning sulfur in a glass chamber. The residues were removed and treated with distilled water to make a 50 percent mixture. All of the extracts were toxic to tomato foliage (Table 15). Quantitative analysis of 5 c.c. samples of the extracts yielded zinc, and the paint residue yielding the smallest amount of zinc sulfate caused the least injury. None of the extracts contained more than a trace of sulfides or sulfites, from which it may be inferred that sulfurous acid is not involved in the problem of injury. The injury to tomatoes in commercial houses proceeds gradually and continuously for a long time and often extends into the second and later plantings after fumigation. This suggests a gradual release of the soluble toxic salt into the drip. A 1 percent solution of chemically pure zinc sulfate is very injurious to tomato foliage, and Read and Orchard (35) found that a 0.3 percent solution is the maximum concentration tolerated by chrysanthemum plants without noticeable injury.

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[4] Paints were supplied by the Sherwin-Williams Company, Chicago, Illinois, and by the Norfolk Paint and Varnish Company, North Quincy, Massachusetts.

In a final experiment six proprietary white paints selected to contain different amounts of zinc oxide and varying otherwise in their composition were painted on wooden panels. The same procedure of fumigation and collection of the fumigated residue was followed, and 10 grams of dry residue were added to 40 c. c. of distilled water. The extracts were tested for sulfides and sulfites and analyzed for sulfates and zinc. Small samples of the extracts were atomized on tomato foliage in the greenhouse. The degree of injury was recorded 3 days after the treatment (Table 16).

The analyses confirm the results of the previous experiment. Soluble sulfides and sulfites were lacking or never more than a trace. The amount of zinc recovered from the extracts and the degree of injury to the test plants were in rather definite proportion to the amount of zinc oxide pigment in the paint. The Lucas paint, which contains 5 percent zinc oxide, yielded after fumigation the smallest amount of sulfates and zinc and caused no injury. The DuPont, Lowe Bros., and Kyanize paints, containing 27, 25, and 33 percent zinc oxide pigment respectively, yielded the largest amounts of soluble sulfates and zinc salts and caused the most injury to tomato foliage.

The Lucas and particularly the white lead paint residues on the wooden surfaces were dry and firm upon the removal of the panels from the humid sulfured chamber. The other paint residues were soft and greasy. The problem of compounding a paint for interior greenhouse use that will not be softened and shed by the action of sulfuric acid from the burning of sulfur is beyond the scope of this study, but its significance is to be noted as a matter of record. There is some suggestion of the value of the carbonates of lead and calcium in the composition of the paint as a deterrent to this condition.

Judging from the results reported in Table 16, a small amount of zinc oxide in the composition of paint, e. g., as much as 5 percent, may be tolerated. However, it would seem safer to exclude zinc oxide altogether from interior greenhouse painting. Read and Orchard (35) stated that the burning of sulfur is not advised except when the interior painting is free from zinc. The former precaution seems preferable, since sooner or later the occasion may arise for burning sulfur between crops as a sanitary pest control measure. Undoubtedly, the amount of plant poison dissolved in the drip is increased slightly by the fact that all zinc pigments in white paints contain a trace to small amounts of zinc sulfate (51).

Reaction with Metal Surfaces and Trellis Wire

Aside from the plant injury from metallic salts dissolved in the drip water after fumigation with burning sulfur, the greenhouse interior metal construction is corroded and the usefulness of the trellis wire is greatly reduced. On galvanized metal surfaces the chemical salt formed during the fumigation period has the properties of white vitriol (zinc sulfate). Sulfur dioxide from burning sulfur is converted quickly into sulfurous and sulfuric acids as is suggested by the thick deposit of the white crystalline salt on galvanized metal surfaces at the end of the fumigating period. Kadow et al. (25) mention the formation of a greenish yellow salt of possibly zinc thiosulfate and the probability of its oxidation to zinc sulfate.

In the case of injury on tomatoes which came to the writer's attention in the spring of 1937, all of the damage was confined to plants directly below rusted iron pipes and span supports. In this instance an excessively large dosage of sulfur was burned previous to the removal of the preceding planting of tomatoes. Such a condition could be avoided by painting the iron with white lead or zinc-free paint. The same protection from the formation of chemical residues harmful to plants can be obtained by painting the metal gutters, posts and other overhead metal construction.

TABLE 16.—ANALYSES OF RESIDUES OF PROPRIETARY WHITE PAINTS EXPOSED TO FUMIGATION WITH BURNING SULFUR, AND ACTION OF EXTRACTS ON TOMATO FOLIAGE

Paints	Zinc Oxide Percent	Sulfides	Sulfites	Sulfates (SO_3) Percent	Zinc Percent	Suspension	Degree of Injury to Tomato
DuPont[1]	27	None	Trace	4.90	5.72	Fair	Severe
Lowe Bros.[2]	25	None	Trace	4.80	5.62	Fair	Severe
Lucas[3]	5	None	None	0.78	0.64	Poor	None
White Lead	0	None	None	None	None	Poor	None
Norfolk[4]	15	Very slight trace	Trace	3.62	4.36	Fair	Slight
Kyanize[5]	33.3	None	Trace	4.60	5.38	Fair	Severe

[1] DuPont Prepared Paint 40. Outside White
Pigment 65%; Vehicle 35%
White Lead....................30%
(Basic carbonate white lead 52%; basic sulfate white lead 48%)
Titanium Barium Pigment.........38%
Zinc Oxide....................27%
Silicates.................... 5%

[2] Lowe Bros. High Standard House Paint. White 328
Pigment 65%; Vehicle 35%
Basic Carbonate White Lead.......37%
Basic Sulfate White Lead..........13%
Zinc Oxide....................25%
Titanium Dioxide................12.5%
Magnesium Silicate...............12.5%

[3] John Lucas & Co. Lucas Tinted Gloss Paint. Inside White
Zinc Oxide.................... 5%
Titanium Pigment................35%
Calcium Carbonate............... 7%
Linseed Oil....................14%
Varnish.......................33%
Drier......................... 1%
Volatile Thinner................ 5%

[4] Norfolk Paint & Varnish Co. T. L. Z. Paste White
Lead Sulfate....................15%
Titanox A..................... 6% (Titanium dioxide)
Zinc Oxide....................15%
Titanox B.....................30% (Barium sulfate 70%; Titanium dioxide 30%)
Asbestine.....................20%
Lead Titanate...................14%

[5] Boston Varnish Co. Kyanize 600. Outside White
Pigment 62%; Vehicle 38%
Carbonate of Lead................33.3%
Zinc Oxide.....................33.3%
Titanox.......................33.4%

Because trellis wires cannot be easily or satisfactorily painted, the matter of an inert wire offered a further problem of study. Different kinds of wire were obtained for experimental tests. After exposure to burning sulfur fumigation in a moist atmosphere, the wires were scraped to remove the chemical residue produced from the reaction, and 5 percent suspensions in distilled water were made. The filtrates were applied to lettuce and tomato leaves with an atomizer and the results noted (Table 17).

TABLE 17.—ACTION OF BURNING SULFUR FUMIGATION ON WIRE AND TOXICITY OF EXTRACT OF THE RESULTING RESIDUE TO PLANT FOLIAGE

Type of Wire	Residue	Degree of Injury from Extract		Price[3] per Cwt. No. 16 Wire
		Lettuce	Tomato	
Stainless Steel[1]	None	None	None	$76.75
Bethanized Steel[1]	Thick white	Severe	Severe	7.045
Tinned Steel[1]	Moderately rusted	None	None	6.345
Zinc Galvanized Iron	Thick white	Severe	Severe	5.995
Black Enameled Copper[2]	None	None	None	10.000
Uncoated Steel Wire				6.75

[1] Furnished through the courtesy of Bethlehem Steel Company, Bethlehem, Pennsylvania.

[2] Furnished through the courtesy of Essex Wire Corporation, Detroit, Michigan.

[3] Prices are of December 1, 1936, by Philip A. Rand, Boston, Massachusetts.

Stainless steel wire is steel throughout with some alloys. Bethanized steel wire is a special zinc galvanized steel wire. Tinned steel wire is coated with tin. Black enameled copper wire is coated with a black enamel. These wires were compared with zinc galvanized iron wire, the common grade of wire used in the greenhouse for supporting trellised plants. The 5 percent extracts of the residues from the zinc-coated wires were very injurious to lettuce and tomato foliage, but extracts of residues from tinned, enameled, and stainless steel wires were not. The use of zinc galvanized wires in greenhouses where sulfur is burned invites serious drip injury to the succeeding planting. The injurious substance formed is zinc sulfate and the amount of damage is obviously influenced by the amount of sulfur burned and moisture conditions. Tinned steel wire, which compares favorably in price with galvanized iron wire, reacted with the sulfur gas, judging from the presence of a moderate amount of rust-colored residue, probably iron sulfate; but a 5 percent extract of it was not injurious to lettuce and tomato foliage.

In a further experiment the percentage of water-soluble material formed by the reaction and the character of the soluble residue were determined. Water extracts of these residues (5 and 2½ percent strength) were atomized on tomato foliage for toxicity values (Table 18). The percentage of soluble material in the residues was most pronounced with Bethanized zinc galvanized wire. The severity of injury was definitely correlated with zinc sulfate. The 5 percent extracts of the residues from tinned and uncoated steel wires were only slightly injurious and the action of a 2½ percent extract was negligible. Therefore, uncoated or tin-coated steel wire would be preferable to zinc galvanized wire in greenhouses so far as compatibility with burning sulfur fumigation is concerned. The cost of the stainless steel wire, which did not react, is, however, prohibitive.

TABLE 18.—ANALYSIS OF RESIDUES ON WIRES AND ACTION OF WATER SOLUBLE EXTRACTS ON TOMATO PLANTS

Type of Steel Wire	Character of Residue	Qualitative Test for						Soluble Material	Degree of Injury to Tomato Foliage	
		Fe	Cr	Sn	Ni	Zn	SO_4	Percent	2.5 percent Extract	5 percent Extract
Stainless	White powdery "bloom"	Tr	Tr		—		—	28.8	None	None
Bethanized	Thick white	—				+	+	98.2	Severe	Severe
Tin Coated	Thick dark brown	+		—			+	66.3	Trace	Slight
Uncoated	Thick pale brown	+					+	76.6	Trace	Slight

Other Considerations

The rate of burning sulfur has a definite bearing upon the extent of the reaction with metal and zinc paint. In the writer's experiments, dosages ranging from 1 ounce to 1 pound of sulfur in a gas-tight greenhouse of 1,500 cubic feet, when the gas was confined for 24 hours, were lethal to the fungus. Under greenhouse conditions, 4 pounds to 10,000 cubic feet, divided into two heaps, was lethal to tomato plants and spores of tomato leaf mold, white fly, and aphis. Drip injury to succeeding plantings was reduced to small relative or negligible importance in several large greenhouses where sulfur was burned at this rate, and the growers expressed satisfaction with the destructive effect of the treatment upon plant life and the common insects.

While the reaction occurs at small ratio treatments, it becomes even less significant or negligible if dry conditions are obtained for the fumigating period. In view of the extensive amount of vine and foliage and the moist condition of the soil, high relative humidity and water of condensation are often difficult to avoid. The precaution of allowing the beds to dry off at the end and the use of pipe heat should produce the dry greenhouse conditions necessary to render fumigation safe.

As a further precaution against drip injury, the poisonous residues on metal and paint can be more or less completely removed by thoroughly hosing down the greenhouse interior with water or with a 5 percent solution of sal soda. The influence of the soda solution on the resulting reaction of the soil suggests a further problem. Since the burning of sulfur at the rate of 4 pounds to 10,000 cubic feet under dry conditions has not produced drip injury of any consequence in various trials observed, there would not seem to be any need for washing down the greenhouse interior after the fumigating period.

Formaldehyde Fumigation

In view of the corrosive action of sulfur dioxide on metal, wires, and painted surfaces in the greenhouse, and the danger of damage to the succeeding crop from the metal and paint drippings, it might appear desirable under some conditions to rely on other materials to eradicate infestations of red spider mite. European reports recommend thoroughly washing down the interior and exterior of the greenhouse with cresylic acid emulsion, phenol solution, or formaldehyde (1,20,36) to kill mites and fungous spores. The greenhouse is tightly closed for about four days to maintain a killing atmosphere and then cleared out. Judging from one report the washes are the more modern method of disinfestation; but according to a more recent report the treatment is apparently no more efficient than sulfur dioxide in destroying the mites in crevices and cracks. Under our conditions the disinfestation of the vines and interior with a wash before clearing out would be difficult and impractical and is not justified in view of the efficiency of such fumigants as naphthalene and hydrocyanic acid gas which, unlike sulfur, are inert to metal and paint even at high dosages. Both eggs and mites succumb to these treatments.

Both naphthalene and hydrocyanic acid gas, even when generated in large excess, are inert to the spores of the tomato leaf mold fungus. In two separate experiments in a tight greenhouse of 1,500 cubic feet, Cladosporium spores were exposed to 8 ounces of vaporized naphthalene for 72 hours at a temperature of 70° to 80° F. and to 16 ounces for 4 days at a temperature of 80° to 86° F. In the latter case there was a heavy deposit of naphthalene on the glass, but this had all disappeared at the end of the 4-day period. There was no lethal effect on the spores. In the same volume of atmosphere, hydrocyanic acid gas was generated from sodium cyanide (10.6 grams), sulfuric acid (16.5 c. c.), and water (22.5 c. c.) and confined for 48 hours. In multiples of this dosage up to 15 times, not the least effect was shown on the viability of the spores of *Cladosporium fulvum* Cke. and *Botrytis cinerea* Pers. These results are in line with the generally accepted view that naphthalene and hydrocyanic acid gas lack fungicidal value. When either of these insecticides is used, it would seem desirable to fumigate further with a fungicide to complete the disinfestation of the greenhouse interior. The burning of sulfur in small dosages, not in excess of 4 pounds per 10,000 cubic feet, is lethal to fungous spores and most insects, and is justified in view of its negligible cost and practical use. Where a definite prejudice against sulfur exists, formaldehyde fumigation may be substituted.

The findings and opinions as to dosages of formaldehyde gas lethal to the spores of the tomato leaf mold fungus are quite inconsistent as may be noted from a study of Table 19. In addition, Williams (54) noted that the fungus in culture was killed on exposure to formaldehyde vapors for one hour and that spores exposed for 8 hours were killed, but the concentration of the gas was not stated.

TABLE 19.—CONCENTRATIONS OF FORMALDEHYDE REPORTED TO BE TOXIC TO SPORES OF *Cladosporium fulvum* CKE.

(Amounts per 1,000 cubic feet.)

Authority	Formaldehyde Fluid Ounces	Permanganate of Potash Ounces	Period	Remarks
Makemson (26).....	48	23	24 hours	Not lethal
Small (44, 46)......	3.2	2	Not stated	Almost completely lethal
Parker (33).........	5		24 hours	Good results
Van der Meer (52) ..	1	½	Not stated	Minimum toxic dose in laboratory

Some tests were conducted in a gas-tight greenhouse of 1,500 cubic feet. Tomato leaves bearing the fungus were exposed for 24 hours. The reacting chemicals were used in increasing amounts from 2 to 10 fluid ounces of formaldehyde with 1.6 to 8.3 ounces of permanganate of potash. All dosages were lethal to the spores of the fungus. In a greenhouse of 10,000 cubic feet, ratios as low as 24 fluid ounces of formaldehyde and 20 ounces of permanganate of potash, with ventilators closed for 24 hours, killed both spores and plants. This appeared to be the minimum lethal dosage under greenhouse conditions, since ratios of 20 fluid ounces of formaldehyde and 17 ounces of permanganate of potash to 10,000 cubic feet, and lower ratios, were not generally toxic to the fungus. In a greenhouse of 31,000 cubic feet, 96 fluid ounces of formaldehyde and 80 ounces of potassium permanganate, which is stronger than the 24-20-10,000 ratio, were lethal to Cladosporium spores and tomato plants but not to the greenhouse white fly. For houses that leak more or less, a ratio slightly higher than the recommended dosage is desirable.

In fumigating with formaldehyde gas, vessels of rather large volume are necessary to guard against overflow of the foaming liquid during the reaction. A 5-gallon vessel about 8 inches in diameter for each 10,000 cubic feet is suggested. The vessels should be narrow enough so that the crystals of potassium permanganate are covered by the formaldehyde. The required amount of liquid is placed in each container. The required amount of potassium permanganate is weighed out in paper sacks and set beside each container. These are added to the vessels, beginning with the one farthest from the exit. A quiet atmosphere is desirable for an effective fumigation and the greenhouse should be closed tight for 24 hours.

The cost of fumigating 10,000 cubic feet of greenhouse with formaldehyde at the suggested ratio is about 53 cents as compared to 16 cents for sulfur on the basis of 4 pounds to 10,000 cubic feet. In view of the large difference in cost and the lack of insecticidal effect from formaldehyde, the burning of sulfur in small amounts for fungicidal purposes seems preferable. For a more complete kill of the red spider mite, a supplementary fumigation with either naphthalene or hydrocyanic acid gas is recommended. Formaldehyde, naphthalene, and hydrocyanic acid gas are inert to paint and metal but lack the merit of a satisfactory disinfestant in being only either fungicidal or insecticidal.

Chemical Soil Sterilization

Formaldehyde when used as a soil sterilizing agent produces a greenhouse atmosphere lethal to fungous spores. Carbon disulfide emulsion when used on the soil to kill soil-infesting nematodes produces an atmosphere that is lethal to most insects. The application of both chemicals in combination to eradicate soil-inhabiting fungi and nematodes produces a strongly lethal greenhouse atmosphere. To obtain a thorough fumigation, the concentration of these gases should be maintained for two to three days by keeping the ventilators tightly closed.[5] Since soil-sterilizing chemicals are applied after the plants are cleaned out, the fumigation of the interior resulting from chemical soil applications does not do what is accomplished by the disinfestation of the old infested vines.

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[5] The use of these chemicals for sterilizing greenhouse soil is described in Mass. Agr. Expt. Sta. Bul. 292, "Carbon Disulfide Emulsion for the Control of the Root-Knot Nematode."

SUMMARY

In Massachusetts, tomato leaf mold, due to the fungus *Cladosporium fulvum* Cke., is of importance only in greenhouse culture. Its occurrence is associated with the off-heating or warmest season of the year when the mean maximum relative humidity and temperature are highest and when the difference between the inside and outside mean minimum temperature is least.

The successful control of the disease involves cultural practices, greenhouse management, greenhouse location and design, and the use of chemicals for the disinfestation of the greenhouse interior and the protection of the plants from infection.

Light and free circulation of air contribute to the control of the disease. These conditions are promoted by the proper spacing of the plants and pruning.

Careful bottom-watering makes for dry foliage and is an aid to the control of the disease. Overhead watering or watering with the open hose should be avoided. Watering should be done in the morning and on bright days to insure, so far as possible, dry conditions at night.

Ventilation to prevent abnormal atmospheres such as high temperatures, stagnant air, and high relative humidity is intimately bound up with the problem of control. The need for adequate ventilating area on all sides and both spans of the greenhouse is imperative in tomato culture to permit the closest approach to normal or outside atmospheres during the off-heating or critical season.

Heat employed intelligently with ventilation late in the spring and early in the fall season of growing can delay the progress of disease, or through careless use may readily encourage an epidemic.

Heat and ventilation to maintain inside minimum temperatures of 60° to 65° F. as the outside temperatures drop to 50° late in the spring and early in the fall, and full ventilation at other times during the milder critical months would appear to be the most economical method of control. During the heating months, periods occur when the outside temperatures converge closely upon the inside minimum growing temperature of 60° F. and render control of the relative humidity difficult. Otherwise the wide difference in temperature and the resultant influence on the relative humidity explain the absence or slow development of the disease in the colder months of the year. Condensation of moisture from the air as dew and guttation from the plant itself contribute to the progress of the disease and can be prevented by cultural and greenhouse management practices.

Good management in contrast to poor management controlled the disease rather well in some seasons, but in others was less effective.

Several automatic or mechanical systems of air conditioning are described. Controlled relative humidity below 85 percent within a temperature fluctuation of 60° to 75° in conjunction with forced air was contrasted with a minimum fixed temperature of 60° F. and hand ventilation. Better disease control under the automatic humidity control was not accompanied by better yields, and the installations were too expensive to warrant commercial use. A constant minimum temperature control has many advantages over hand control and is worthy of installation in commercial practice.

Control of the disease is intimately bound up with greenhouse location and design. Location with regard to good air circulation is an important aid to successful management.

The vaporization of sulfur at regular and close intervals beginning in April in the spring growing season and before planting in the fall season is an efficient contributory method of control. The sulfuring of the heating pipes is not a comparable method of vaporizing sulfur and may encourage rapid progress of the disease.

Because of unsatisfactory protection of the lower surfaces of tomato leaves, and conditions peculiar to greenhouse culture, the use of fungicidal sprays and dusts is not effective.

The disinfestation of the greenhouse interior with chemical fumigants is a desirable sanitary measure and should be done just before the finished planting is cleaned out. Burning sulfur and formaldehyde have received the widest recognition for fumigation. The burning of sulfur is customary because it is economical, practical, and lethal to both fungi and insects.

The usual recommended rate of application of 1 pound of sulfur to 1,000 cubic feet is excessive and invites dangerous chemical reactions with galvanized metal surfaces, iron pipes, and paints containing zinc. The resulting soluble residues in the drip water injure the succeeding plantings. The burning of 4 pounds of sulfur to 10,000 cubic feet under relatively dry conditions is safe. This application is lethal to tomato leaf mold spores, plant life, and the common insects except the red spider mite. Hydrocyanic acid gas and naphthalene vapors are inert to metal and paint and in strong enough dosages are lethal to red spider mites and eggs but have no fungicidal value. Either should supplement the sulfur treatment to obtain a more complete disinfestation of the greenhouse interior. Paints containing zinc should not be used in interior greenhouse painting, and metal surfaces should be protected with white lead or paints free of zinc. Where sulfur is customarily burned, tinned or uncoated steel trellis wires should be used instead of zinc galvanized iron wires. Dry greenhouse conditions during the sulfur fumigation period should prevail.

Formaldehyde vapors have a lethal action only on fungi and are inert to metal and paint. Under commercial greenhouse conditions a dosage of 24 fluid ounces of formaldehyde and 20 ounces of potassium permanganate to 10,000 cubic feet is lethal to plants and to tomato leaf mold spores. Cost of the materials in these proportions is about 53 cents as compared with 16 cents for sulfur at the rate of 4 pounds to 10,000 cubic feet.

The dual value of sulfur, its practical utility, and its economy lead to its endorsement in practice.

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Haying in the Rain

A Study of Grass Silage

By J. G. Archibald and C. H. Parsons

The ensiling of grasses and legumes is rapidly finding favor among farmers. This bulletin, based on three years of study, deals with the practical phases of the subject.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

"HAYING IN THE RAIN"

A STUDY OF GRASS SILAGE

By J. G. Archibald, Research Professor, and C. H. Parsons, Assistant Professor of Animal Husbandry.

"Haying in the *rain*! What nonsense is this?" asks the hardheaded Yankee farmer. "Those fellows better go and have their heads examined." Ten years ago nobody would have questioned this terse dismissal of such apparently fanciful tommy-rot. But now! Haying in the rain, or at least in weather entirely unsuited to ordinary haymaking, is not only possible, it is actually being done by hundreds of these same hardheaded farmers scattered all through the northeastern United States.

And how is it being done? By the simple device of storing the grass as ensilage, instead of by the time-honored method of drying it into hay if and when the weather permits. It all seems so simple, now that the practice has become established, the wonder is that it wasn't thought of long ago.

As a matter of fact the idea of ensiling grass is not new. It was tried a good many years ago when corn was first stored in this way, but without much success, because those who tried it failed to recognize one fundamental difference between corn and grass.

Corn, because it is high in sugar and starch, ferments readily in the silo with the production of sufficient acid to act as a natural preservative. Grasses and legumes do not contain enough of these readily fermentable substances for their proper preservation in the silo; hence the large percentage of failures when they were ensiled like corn.

This difficulty has been overcome in recent years by the addition of preservatives to the chopped grass at the time the silo is filled. Perfection of this principle in practice has been the key to success in the ensiling of such crops. Its discovery has been responsible for the recent phenomenal development of this method of preserving roughage.

Advantages of Ensiling Grass and Legumes

The advantages of storing grass and legumes in the silo are listed in what is considered the order of their importance, and for the most part are so obvious as to need only simple mention.

1. The crop may be harvested in any sort of weather short of a heavy rain.
2. The crop is all saved — losses of ordinary haymaking which run as high as 40 percent or even higher in unfavorable weather, due to shattering of leaves and leaching by rains, are largely eliminated. The quality of the feed is superior to the best of dry cured hay.
3. Much space is saved — a ton of dry matter stored as silage occupies about one fourth as much room as it does when stored as long hay.
4. The fire hazard is eliminated.
5. The haying operation may be started earlier, with less delays because of cloudy weather, thus completing the harvest sooner and having less of the crop cut when overripe.

Disadvantages of Ensiling Grass and Legumes

The old saying has it, "No loss without some small gain"; conversely there is no gain without some offsetting loss. It would be unfair to mention the advantages of this system of storing roughage and to lose sight of its less desirable features, which after three years' experience appear to be:

1. The necessity of handling approximately three times as much weight as when the grass is made into hay. This drawback disappears in proportion to the amount of extra handling of hay by the old method due to unfavorable weather.
2. The possible need for investment in a type of hay loader that will handle green grass satisfactorily.
3. Some cash expense for preservative.

Preservatives Used

These are of two general types: (1) Those in which the acid needed to prevent spoilage is added directly, and (2) those which contain sugar which ferments to form the needed acid. In the first mentioned type comparatively little fermentation takes place; the process is essentially a pickling.

Examples of this type are:

A mixture of hydrochloric and sulfuric acids, as used in the so-called A. I. V. process. This process was developed in Finland and does an excellent job of preservation. However, practical difficulties attendant upon its use will probably prevent its general adoption in this country.

Phosphoric Acid. A method developed at Cornell University makes use of small amounts of this acid and is being used to a considerable extent, especially in New York State. Detailed information about this method appears on page 17.

Examples of preservatives which are carriers of sugar are:

Dried whey. This material contains about 65 percent of milk sugar, and in trials by one experiment station it proved "the most effective of the preservatives used in increasing the acidity of the silage." Dried whey is known in the feed trade as "milk sugar feed," its present price (December, 1938) being between four and five cents a pound. At this price level it cannot compete with molasses as a source of sugar, but the price may not always be so high. At half its present cost the use of dried whey as a silage preservative might help to solve the problem of overproduction of milk, as it is a by-product of surplus milk.

Molasses. This is by far the most commonly used silage preservative. The practical details of its use in this country were first developed by workers at the New Jersey Experiment Station. In the past four or five years the method has spread all over the country; its best endorsement lies in the fact that the great majority of farmers who have tried the method are continuing to use it. Three years of experience in the ensiling of grass and legumes on the Massachusetts State College farm, coupled with the experience of over fifty farmers throughout the state during the past two years, have demonstrated that the principle is well adapted to our conditions, that skill with the method is quickly acquired, and that the product is readily eaten by cattle and is superior to dry hay for milk production.

Since the molasses method is the one in most general use thus far, a detailed description of it will serve as a general guide for those unfamiliar with the procedure of ensiling these crops.

Details of Making Grass and Legume Silage with Molasses

Suitable Crops

Any of the annual or perennial grasses or legumes or the small grains may be successfully ensiled, provided they are cut at the *proper stage of maturity.*

Time of Cutting

For the grasses the best stage is before bloom, preferably soon after the flowering head or spike has emerged from the sheath. For the legumes early bloom seems best, certainly not any later than full bloom. Where mowings contain a mixture of grasses and legumes, as they usually do, a happy medium will have to be hit upon in order to average up the degree of maturity, as some of the species bloom several days or even weeks earlier than others. The best time for first cutting in the region around Amherst seems to be the first two weeks of June. This may seem a bit early to farmers accustomed to ordinary haying, but whatever tonnage is lost by cutting before growth is complete, is compensated by smaller losses in harvesting, by higher feed value of the younger crop, and by a heavier second cutting.

This past season (1938) silo filling with grass on the State College farm, was begun on May 31 and finished on June 21, over two hundred tons of green hay having seen stored in two large silos.

It cannot be too strongly emphasized that mature grass does not make good silage, especially if placed near the top of the silo. The weight at that point is insufficient to pack it so all air will be excluded, and pockets of mold result.

Moisture Content

For the same reason the crop, even when cut at the right stage, should not be allowed to remain in the field too long on a bright day, more especially spread out in the swath. The best silage results when the moisture content of the crop is between 60 and 75 percent. When it gets below 60 the same difficulty is encountered as noted above for mature grass.

An immature crop that because of unforeseen circumstances has dried to less than 60 percent moisture may, however, be safely used for silage provided it goes into the bottom half of the silo, where it will be well packed and the juices from the upper layers will seep down and be absorbed by it. Even this should not be practiced with material containing less than about 50 percent of moisture. Water added at the silo will help in such a situation, but the silage will not be of as high a quality as if the crop had not been allowed to dry out to any extent.

Excessive moisture is also undesirable since it means handling extra weight and only drains out at the base of the silo. For this reason it is best not to try to operate immediately after a heavy rain. Also if the crop is very succulent (80 percent or more of moisture), as is the case sometimes with young legumes, especially Ladino Clover, it is better to allow it to wilt before loading.

Amount of Molasses

This depends on the nature of the crop. Legumes with their high protein content require more than grasses, as the tendency to rot is greater. Amounts which have given general satisfaction are:

	Per ton of green weight
For grasses or small grains	40 pounds[1]
For grass and clover (50-50)	60 pounds
For clover, alfalfa, or other legumes	75-80 pounds

[1] A gallon of molasses weighs 11 ¾ pounds.

In practice these amounts can only be approximated, but they serve as a useful guide. It is better to err on the side of too much rather than too little. Although most of the sugar in the molasses is converted by the fermentation into lactic and acetic acid, animals are able to use these acids as food so that the loss of nutrients from the added molasses is small.

Whatever the loss may be, the amount of molasses it represents has rendered a valuable service in preserving many times its weight of fodder.

Harvesting

The mowing may be done at any time of day, but as already indicated there will be less weight to handle if the standing crop is allowed to dry off a bit after heavy rain. When the moisture content is about right, the mower may be followed immediately by the side-delivery rake and the loader. Some operators use a windrowing attachment on the cutter bar of the mower as illustrated in Figure 1. At most, the crop should not lie in the swath more than a couple of hours if the day is bright. It is important not to cut more than can be put into the silo on the same day, unless the weather is very damp and cloudy and gives promise of remaining so. Even then the mower should not be allowed to get far ahead of the loader. Six feet is the greatest length recommended for the cutter bar; 5 feet 6 inches is better.

On small fields loading may be done by hand. This is not so hard a task as it may seem on first thought, because, on account of much greater weight per cubic foot, the load should never reach more than half the height of a load of dry hay. (See Figure 2).

Various types of loaders are used for large-scale operations. The standard dry hay loader is not suited to the work without some changes, especially when the crop is heavy and wet from rain or dew. The water causes the ropes to shrink, which in turn pulls out the staples which fasten the ropes to the slats, rendering the elevator useless. This difficulty can be overcome by replacing the ropes with light chains. The type of chain used for window weights has been recommended and is obtainable at most hardware stores. It has also been suggested that the standard slats be replaced by heavier ones made of oak or some other very durable wood. Even then, it is believed that for very heavy crops the standard dry hay loader is not sturdy enough in construction to stand the strain.

Experience at the State College with repeated breakages of this type of loader led to the purchase this past season of an all metal loader designed to handle either green grass or dry hay successfully. This loader is of the raker bar-cylinder type with galvanized steel deck, and is more rugged in construction than the ordinary dry hay loader. It has been reasonably satisfactory in operation but will not pick up grass from the swath without tangling at the sides of the deck, particularly when the machine is turning corners. This caused so much delay that loading directly from the swath was abandoned in favor of use of the side-delivery rake with subsequent loading from the windrow. Beginners are cautioned against rolling up too large a windrow, especially on hilly fields or where the ground is soft. Figure 2 shows the loader in operation.

The work is planned so as to keep the loader and tractor on the move as much of the time as possible. Drawing to the silo is done for the most part with teams. Where the haul is short and the loader is run at an average rate, two teams can keep ahead of the chopper, especially if an extra wagon or two is available. On fields located at some distance from the silo, the teams have been given a boost with a two-ton truck when it could be spared from other work. Some operators with considerable experience in putting up grass or legume silage use only trucks for hauling, the dump body type, 1½ ton capacity, being popular for the job. When such a truck is used, the load is dumped at the cutter and the truck returns to the field immediately.

Filling the Silo

Any type of cutter may be used, but the older and smaller kinds designed for corn must be fed more slowly than a hay chopper. Experience shows that any type of cutter will clog more readily on grass than on corn, but the types especially designed for hay chopping or grass silage have an enormous capacity when fed uniformly. They have the further advantage that they can be used for corn without any adjustments other than for size of cut. The power necessary to operate the largest size (19″ throat) which is what has been used in this work, is 20 H. P. Both electric motor and tractor have been used satisfactorily.

Arrangements for feeding the cutter vary with different set-ups. Figure 3 shows the one in use on the State College farm. The grass is unloaded from the wagons onto a feeding table and from there goes to the traveling apron of the cutter. Feeding direct from the wagon to the cutter apron has been tried but must be done more slowly and carefully in order to avoid clogging. The feed table in between makes uniform and rapid feeding of the cutter much easier. The table is constructed of rough lumber and is 8′ long, 4′ 7″ wide, and 3′ 9″ high.

In the set-up mentioned above, where the load is dumped at the cutter, a considerable saving of labor has been effected by digging a trench to set the cutter down into, so that the feed apron is at or near ground level. This trench must run the whole length of the machine, since the power pulley must be perfectly level.

Precautions against clogging of the blower pipe include, (1) uniform feeding — no large masses of tangled grass, (2) fine chopping — not longer than an inch, half an inch is better, (3) a blower pipe as nearly vertical as possible and of uniform diameter, (4) a freely-swinging distributor pipe with a large funnel-shaped head, and (5) shutting off the molasses before the last few forkfuls of grass are fed into the cutter. The operator should keep a sharp lookout for stones and other trash which are more common than in corn, especially in crops from newly seeded land. Knives should be sharpened every day.

Adding the Molasses

There are numerous modifications of this operation. Figure 3 shows the set-up used at the State College in 1936 and 1937. Here the molasses was added by gravity, being run onto the unchopped grass just before it went through the feed rolls. This past season, the same gravity feed arrangement was used but the molasses was run into a funnel which led into a 2″ pipe tapped into the base of the blower. This arrangement is cleaner and there is no loss of molasses. The only equipment necessary is a farm wagon; some short lengths of stout plank for blocking; a length of 1½″ pipe[1] about 4′ or 5′ long, fitted at one end with a gate valve;

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[1] Two inch pipe is better if there is room between the hoops.

three short lengths of 2″ pipe with one 135-degree and one 90-degree elbow; a 1″ nipple and bushing; a large funnel; a pipe wrench; and an expansion bit.

Three or four casks of molasses are loaded on the wagon, which is then backed into position as shown in Figure 3, one of the casks is elevated further by means of short planks laid across the wagon box, a hole is bored as near the chime as the hoops will permit, the pipe is threaded in, and, with the valve for control, all is in readiness.

The molasses may be added undiluted, straight from the original cask, or it may be mixed half and half by volume with water. The former practice means less labor and a cleaner job; but unless feeding of the cutter is slowed up to somewhat less than its maximum capacity, undiluted molasses will not flow fast enough, especially on cool days, to supply the amounts needed for clover and alfalfa (75 lb. per ton).

In such a situation an extra man is needed to carry water, measure molasses from a stock cask to a mixing cask, and keep the mixture thoroughly stirred. However, the time saved by the rest of the crew, both at the silo and in the field, because of maximum load at the cutter, will more than offset the labor of this extra man. The set-up in Figure 3 is for such an emergency, which will not arise when only 40 pounds of molasses per ton is required, as is the case for grasses and small grains.

Regulating the Flow of Molasses

There is a knack to this that can be acquired only by experience. Temperature, head of molasses in the cask, size of pipe, and rate of feeding the crop to the cutter, are all factors that have to be reckoned with. Since these vary from farm to farm, and, in the case of temperature and head of liquid, from time to time during the day, the amounts prescribed can only be approximated, and no hard and fast rule can be set down. The following will be of help:

A stream of molasses (undiluted) that fills a quart bottle in:	Delivers the following amount of molasses in 10 minutes:
40 seconds	40 pounds
30 "	60 "
20 "	80 "

If the molasses is diluted with water, half and half by volume, the stream must be enough larger to fill the bottle in half the above time limits.

An average rate of cutting for the larger machines is a ton in ten minutes.

Further checks on the amount of molasses being added are:

	A 54 gallon cask for:	A cask should last (actual chopping time):
Grass alone.............	14 tons green weight	2 hrs. 20 min.
Grass and legumes (50-50)	11 " " "	1 hr. 50 min.
Legumes alone..........	8 " " "	1 hr. 20 min.

Where scales are not available to weigh the load, it may be of further help to know that the average weight of 111 loads at the State College, season of 1938, was 3,450 pounds net. At a chopping rate of 10 minutes per ton, such a load goes through in about 17 minutes.

After some experience has been acquired, with the above information to check him occasionally, the operator can judge quite well by the size of the molasses stream whether or not enough is being added. Some of the new machines have a device attached to the feed roll of the cutter which automatically regulates molasses flow by opening or shutting the valve in the molasses line as the roll rises and falls with variations in rate of feeding the crop to the cutter. When no material is passing through the rolls, the valve is closed completely. This arrangement does not, however, take care of the rate of flow, which must be predetermined and a second valve in the line set accordingly. Figure 4 illustrates such an arrangement.

Molasses may also be dispensed by force feed or by a small rotary pump with suitable connections. Both of these methods are more convenient than the gravity method, doing away with much heavy lifting, but they require a larger investment in equipment.

For either method, the molasses cask may remain on the ground convenient to the cutter; the molasses flows through a flexible hose line instead of through a pipe. In the force feed method, the small hole bored in the bung, which in the gravity system serves only as a vent, is fitted with a tire valve. A few strokes of an ordinary tire pump as needed will keep the molasses flowing uniformly. Fifteen pounds pressure is sufficient; a small pressure gauge placed where the operator can keep an eye on it is a great convenience for this set-up. Caution should be used not to apply too much pressure. One operator forced the head out of a cask by too vigorous use of the pump. A larger pipe would help in such a situation by reducing friction and thus permitting freer flow.

Suitable connections for a small rotary pump are described and illustrated in *Hoards's Dairyman* for May 10, 1938 (p. 261).

Distribution in the Silo

It has been our practice to keep a man in the silo at all times when the cutter is in operation. Even distribution is the secret of uniform packing, and this is best accomplished by the use of a distributor kept constantly in motion and directed in turn toward every part of the silo. The sides should not be heaped up at the expense of the middle, or the mass will pull away from the walls as it settles, resulting in moldy silage all around the edge. Neither should the middle be allowed to pile up, or the heavier parts of the chopped grass will roll down the cone to the edge, resulting in a silage not at all uniform in quality and feeding value. If the attendant does a good job with the distributor, much tramping is unnecessary except to compact the top layers when the silo is full or nearly so, and as the silage settles.

A tight silo is just as important as it is for corn, perhaps even more so. Strips of tar paper or building paper should be tacked inside, over the doors, as the silo fills.

Sealing the Silo

Unless the silo is properly sealed, waste from spoilage will be excessive. Several methods are in use. Details of one that has worked well at the State College are:

1. Level off and thoroughly tramp the last load of good fodder.

2. Cover the leveled mass with strips of building paper, cut long enough to turn up a foot or so against the silo wall.

3. Blow in on top of the building paper some poor hay or straw mixed with wet sawdust and tramp well. There need be only enough of the poor roughage to keep the sawdust from spilling through the crevices of the apron and feed rolls. Two large dumpcart loads of sawdust have been found sufficient for a silo 14 feet in diameter. Sand might be used instead of sawdust, but of course it could not be run through the cutter.

Another method that is said to give good results is to sow oats thickly over the top of the mass. The mat of roots from the sprouting grain seems to be effective in excluding the air.

Intervals between spells of filling should not be longer than 48 hours at the most, and preferably not more than 24 hours, as the unprotected green material spoils rapidly. Some operators have found that adding water between fillings helps to keep spoilage down.

When the filling job is completed, the cutter, blower, and blower pipe should be thoroughly flushed with water from a hose to clean off any residue of molasses.

Chemical Changes and Losses Taking Place in the Silo

The changes are similar to those which occur in corn. The most important are:

1. Breaking down of considerable of the protein to its constituent amino acids; production of some ammonia.

2. Formation of lactic and acetic acid from the sugars and starches; incidental production of some methane, alcohol, and carbon dioxide.

Losses may be classified into:

1. Unavoidable losses, due to the escape of the gases methane and carbon dioxide, noted above as products of fermentation. In a tight silo with silage well packed and the top properly sealed, most of the loss will be in this category. It may amount to as much as 12 percent of the total weight of the crop, but is usually between 5 and 10 percent.

2. Losses which can be controlled, due for the most part, to seepage and growth of molds. Some seepage is inevitable, but it may be kept at a minimum by not harvesting the crop when it is very wet, by allowing very succulent crops (Ladino clover, for instance) to wilt before storing, and by putting the less succulent material in the bottom half of the silo where it will absorb the juices seeping down from the upper layers.

That seepage need not be a cause of serious losses is shown by records taken at the State College during the past season. In order to obtain such records, a concrete floor was constructed in a silo of 100 tons capacity, with one central drain leading through glazed tile with watertight joints, to a catch basin outside and below the base of the silo. To insure free drainage, a cast-iron dome was placed over the strainer at the inlet of the drain. A self-recording device for measuring flow of liquid and for sampling the liquid was placed under the drip from the tile in the catch basin.

The amount of liquid which drained off was slightly more than 28 gallons, or about two thirds of a barrel. The amount of solids in this liquid was determined on seven different occasions and averaged almost exactly 5 percent, or a total of not quite 12 pounds of solid substance lost by seepage from over 82 tons of silage. Practically all of this drainage occurred during the first ten days after beginning to fill the silo, most of it in the first six days.

Growth of molds may be the cause of serious loss, but can be kept at a minimum in a tight silo with the precautions already noted in the sections on "Filling" and "Sealing."

Changes in composition of grass, depending upon whether it is made into hay or stored as silage, are shown in Table 1. A field on the State College farm, having a uniform stand of grass was divided into halves at silo-filling time in June 1937.

The grass on the entire field was cut and one half of it was cured and stored as hay, while the other half was put into the silo with molasses. The grass that went into the silo was stored within a few hours after cutting; that made into hay lay out for four days and was exposed to rain four times with considerable extra handling as a consequence. The results of analyses of the grass, hay, and silage are expressed in the table as percentages of the dry substance which each contained. This is the only possible basis of comparison since the water content of the grass and the silage was about three times that of the hay.

TABLE 1. — COMPOSITION OF FRESH GRASS AND GRASS STORED AS HAY AND AS SILAGE

	Percentage in Dry Matter				
	Protein	Fat	Fiber	Carbohydrates	Minerals
Fresh mixed grass	11.9	2.3	34.4	43.6	7.9
Hay made from half the lot of grass	9.5	1.9	36.5	46.1	6.0
Silage made from the other half	10.7	3.5	34.7	42.2	8.9

A study of the table shows that:

1. The protein content of the grass made into hay was reduced approximately one fifth, while that of the grass made into silage was reduced about one tenth.

2. The crude fat (which, by the way, is largely coloring matter rather than true fat) was reduced roughly one sixth in the hay. The increase of this constituent in the silage is apparent only, probably being due for the most part to the presence of waxy or resinous material in the added molasses.

3. The fiber (of which a minimum is desired) was practically unchanged in the silage, and was increased relatively in the hay, owing to the loss of other soluble and more valuable constituents.

4. There was a loss of about 3 percent of the carbohydrates in the silage. The gain in this constituent in the hay is relative only, as explained above for fiber. The whole story of hay losses does not appear here, for because of a fire which destroyed the barn in which the hay was stored, samples of the hay after several months storage were not available for analyses. It is generally recognized that in the sweating process which hay undergoes in the mow, considerable of the carbohydrate portion is used up.

5. About one fourth of the minerals were leached out of the hay by the four-day exposure. As in the case of the fat, the increase in minerals in the silage is apparent only, being due to the presence of a considerable amount of these substances in the added molasses. The minerals and the waxy or resinous material, referred to above, represent the portion of the molasses which is not broken down by the fermentation, being left behind as a residue.

It is to be regretted that actual tonnage losses by both methods of storage are not available. As already noted, the hay was destroyed by fire, but losses in the silo for the 1937 season have been ascertained. The loss in dry matter was 13.5

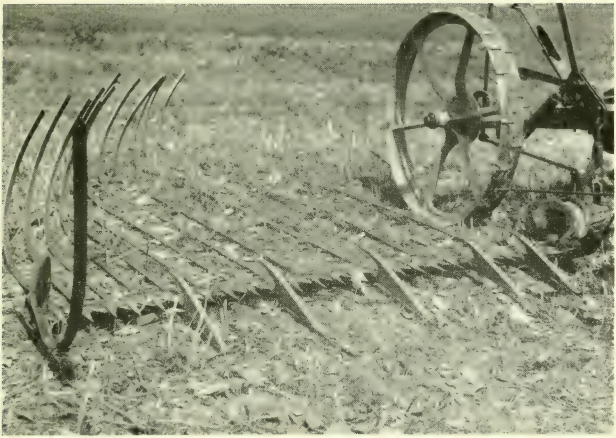

Figure 1. Windrowing Attachment for Mower.
(Courtesy of Mr. Babcock, Ithaca, N. Y.)

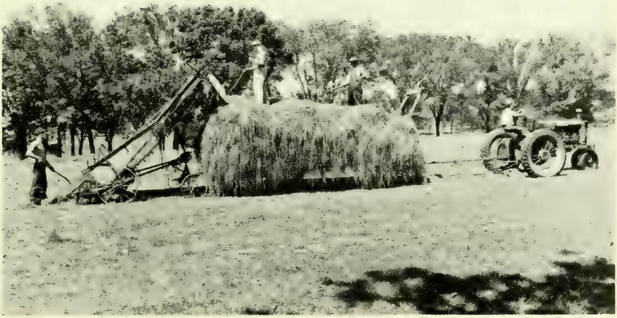

Figure 2. Loading Operations on the State College Farm.
This is practically a full load.

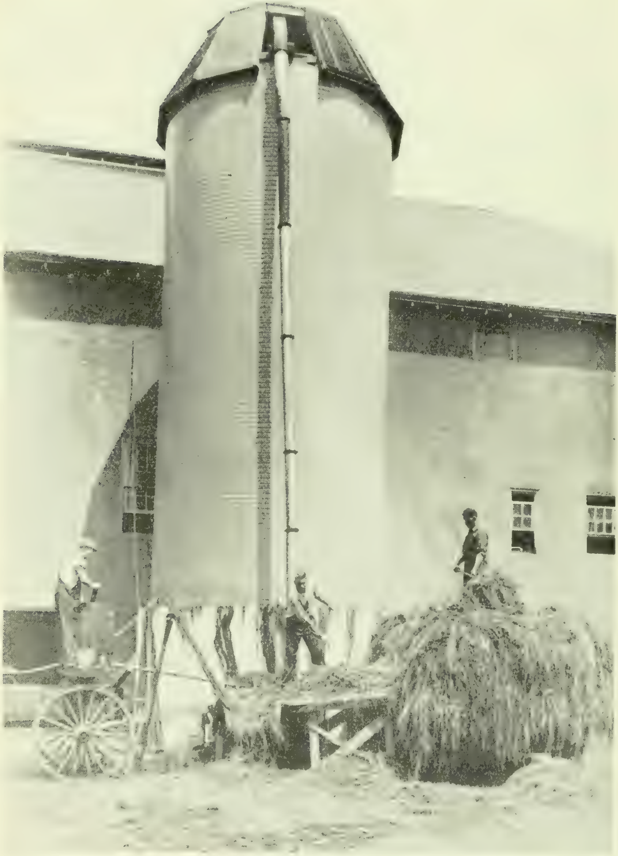

Figure 3. Set-up at the State College for Chopping Grass and Adding the Molasses.

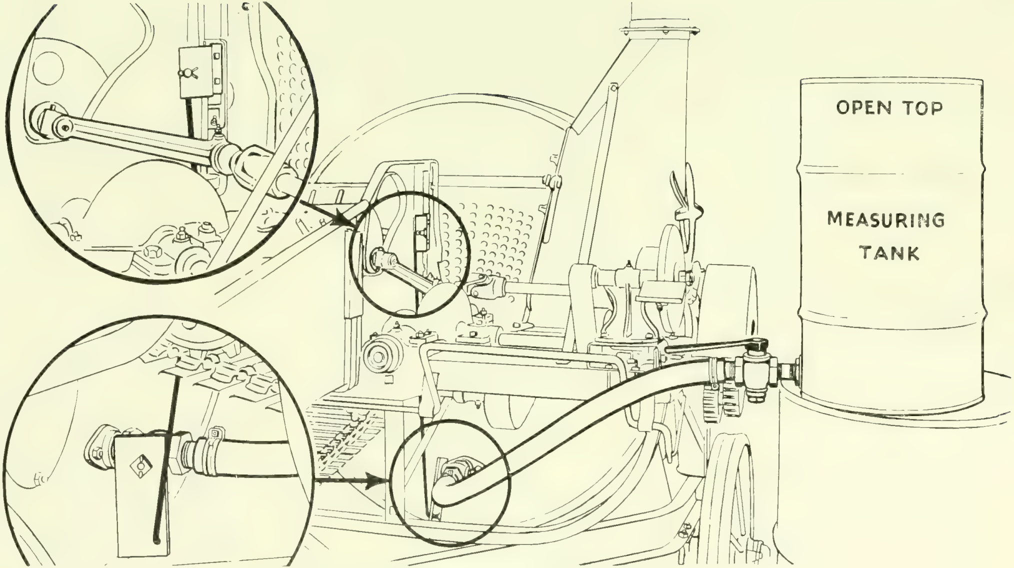
OPEN TOP
MEASURING
TANK

Figure 4. Details of Automatic Device for Regulating Flow of Molasses. (Courtesy of Mr. Frank Hamlin, Papec Machine Co., Shortsville N. Y.)

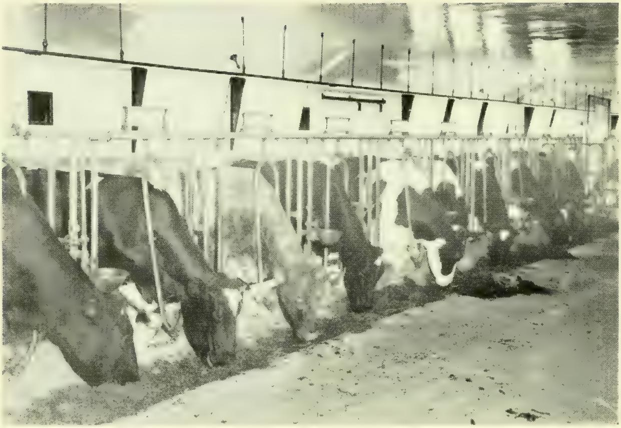

Figure 5. Cows in the State College Herd Eating their Morning Allowance of Molasses Alfalfa Silage.

percent, or about one seventh of the total dry matter stored as green grass. The total loss was much larger than this, but since approximately seven eighths of it was water, the loss in dry matter is of much greater significance. The causes of the loss in dry matter, with their relative importance, were:

	Approximate percentage
Spoilage at top of silo	13
Fermentation loss	7
Seepage from base	80

Loss from seepage was largely eliminated in 1938. At date of writing, the silo has not been opened so the loss from spoilage at the top for this past season is not yet known. Fermentation loss cannot be ascertained until the silage has all been fed out.

The losses were distributed among the several constituents of the dry substance as follows:

	Approximate percentage
Carbohydrates	33
Protein	30
Fiber	22
Minerals	14
Fat	No loss

Chemical Composition of Various Kinds of Silage

Table 2 shows the composition of various kinds of grass and legume silage, along with the average composition of corn silage for comparative purposes.

TABLE 2. — COMPOSITION OF LEGUME AND GRASS SILAGES STORED IN MASSACHUSETTS IN 1936 AND 1937

Kind of Silage	Percentage in Fresh Silage						Carotene, International Units per Pound
	Water	Protein	Fat	Fiber	Carbohydrates	Minerals	
Timothy–Alfalfa–Phosphoric Acid	72.8	4.1	.9	8.5	10.7	2.9	9710
Timothy–Molasses	74.2	3.0	.7	10.6	10.0	1.5	5490
Sudan Grass–Soy Beans–Molasses	75.4	3.4	.5	8.5	10.0	2.1	7980
Alfalfa–Molasses	76.4	3.6	1.0	8.7	8.2	2.0	10210
Orchard Grass–Clover-Molasses	75.9	2.6	1.0	8.0	10.6	1.9	8440
Rye–Molasses	76.3	2.4	.7	8.4	10.4	1.8	—*
Mixed Grasses–Molasses	74.0	2.7	.9	9.0	11.5	1.8	—*
Corn Silage (for comparison) (Average of a large number of samples)	73.3	2.1	.8	7.1	14.9	1.8	8140

*Not determined.

Four of the samples were sent in by interested farmers; the other three were from the State College farm. As would be expected with such a variety of materials, there was considerable variation in composition. In general, grass and legume silages are higher in protein, fiber, and minerals and lower in carbohydrates than corn silage. This statement, coupled with the figures in the table, throws further light on the fundamental reason why corn makes good silage without the addition of any preservative (see page 2). There was a great variation in carotene content of these materials, due partly to such external causes as stage of maturity at harvesting, and packing in the silo.

Consider for instance the second sample in the table, which had the lowest carotene content of the lot. It had also the lowest content of minerals and the highest content of fiber, a combination of factors which indicates that the timothy from which it was made was either very coarse or too mature when harvested, perhaps both. Superficial examination of the sample when received, showed it to be rather stemmy with small spots of mold distributed all through it. Such a condition suggests material too mature to pack well in the silo, leaving tiny air spaces with consequent development of mold and destruction of carotene.

Acidity of Grass and Legume Silages

Several inquiries have been made as to the degree of acidity in this type of silage, and whether it is higher or lower than in corn silage. Determinations were made during the winter of 1937-38 with the following results:

	pH	*Active Acidity* (Hydrogen ions per million of silage)
Grass silage	3.75	178
Alfalfa silage	4.20	63
Corn silage	3.68	209

Since low pH readings mean high acidity and vice versa, the figures mean that the corn silage was more acid than either of the other two. In terms of active acidity, corn silage was somewhat stronger than the grass silage and more than three times as strong as the alfalfa silage. A range between pH 3 and pH 4 is generally considered satisfactory for silage. Below pH 3, the material is probably too acid to be fed continuously to cattle. Above pH 4, the chances of spoilage due to growth of molds are greatly increased.

Temperatures Reached in the Silo

On page 2 elimination of the fire hazard was given as one of the advantages of ensiling grasses and legumes. In this connection, it is of interest to note that the highest temperature recorded by a pyrometer connected to a thermocuple, buried at about the center of the silo, was 93° Fahrenheit. This is in agreement with work done at the New Jersey Experiment Station, which reports temperatures seldom going above 100° Fahrenheit, provided the grass was not allowed to dry out to any extent before chopping. Temperatures in hay mows may run as high as 160° F., and where spontaneous combustion occurs, of course, they are very much higher.

Feeding Practice

The ensiled crop may be fed out at once, but it will keep better from day to day in the silo if first allowed to go through the fermentation process, which reaches completion in a month or six weeks. With legume silages especially, it is of even greater importance than with corn that the diameter of the silo be so adjusted to the size of the herd that the entire surface layer of silage is removed each day.

The usual method of feeding is the same as for corn silage, substituting the grass silage pound for pound. Where the silage consists entirely of alfalfa or other legumes, it may be necessary to feed smaller amounts until the animals become accustomed to the somewhat richer feed. From one half to two thirds the amount usually fed in the case of corn silage is suggested, with a gradual increase to full feed if circumstances warrant it.

Palatability

Legume silage seems to be fully as palatable as corn silage to milking cows. The grass silages fed at the State College have not been eaten as readily as corn silage, but have always been cleaned up before the next feed, except in those occasional instances when lumps or flakes of moldy material escaped notice and were fed out. Young cattle ate the grass silage as readily as they did corn silage.

Experience here has led to the belief that it is not advisable to substitute grass silage entirely for dry hay. Animals fed on silage and grain only for several weeks seemed to be as greedy for dry roughage as they usually are for silage or other succulent feed when they have been restricted for some time to dry feed only.

It has also been observed in the State College herd that when grass silage and dry hay are both fed, the animals clean up their allowance of both much better if hay is fed at one end of the day and silage at the other, than if the allowances of each are halved and fed together. Figure 5 shows some of the State College cows sampling their morning feed of alfalfa silage.

Feeding Experiments

During the winter of 1937-38, extensive trials of the value of this type of silage for milk production were conducted in the State College herd. During the first half of the winter (November, December, and January) it was compared with corn silage, sixteen cows being divided into two groups and fed grass silage and corn silage alternately for five-week periods. During the second half of the season (February, March, and April) the grass silage was compared with dry hay, using the same number of cows for the same length of time as in the first half. Both kinds of silage were fed in identical amounts, the total for each group of cows being the same. The grass silage and dry hay were fed in the ratio of 3 : 1. Other feeds and general care were identical for both groups throughout.

Milk Yields

Results are expressed on the basis of average daily yield of milk per cow, corrected to 4 percent fat, and show:

On corn silage	21.56 pounds
On grass silage	21.57 pounds
On dry hay	27.09 pounds
On grass silage	27.92 pounds

The grass silage was equal to corn silage and somewhat superior to dry hay for milk production.

Gains in Weight

All cows in the experiment were weighed on each of two successive days at the beginning and end of each five-week feeding period. The average individual gains for the entire trial were:

On corn silage	46 pounds
On grass silage	38 pounds
On dry hay	33 pounds
On grass silage	66 pounds

Because of the usual considerable fluctuations in weight common to cows, the difference of 8 pounds in favor of the corn silage has little if any significance. The difference of 33 pounds in favor of the grass silage when compared with dry hay is, however, of sufficient magnitude to be significant. This particular lot of hay, at least, was inferior to the grass silage for body gains.

Average Butterfat Test

This was ascertained by means of three-day composite samples from each group of cows, about midway of each five-week feeding period. The results follow:

	Average fat test
On corn silage	4.32%
On grass silage	4.35%
On dry hay	4.10%
On grass silage	4.23%

Since these tests represent the average of all cows, individuality of the animals as a factor can be ruled out. The small difference between the tests when corn silage and grass silage were compared is, of course, without significance. The somewhat larger difference when grass silage was compared with dry hay may possibly be of some significance as indicating a slightly favorable response in this respect to the silage feeding.

Vitamin A Content of the Milk

This was determined by biological assay with white rats[1] on the composite milk samples taken during the second half of the winter; i. e., when grass was being compared with dry hay. An assay for vitamin A in the milk was not made during the first half of the season. Results appear below.

	Vitamin A (International Units per quart of milk)	
	In March	In April
Cows receiving dry hay	2,172	1,514
Cows receiving grass silage	3,407	1,703

The much larger difference in favor of the grass silage in March than in April is attributed to the fact that the lot of silage being fed at that time was probably the highest in carotene content of any fed all through the season. It contained a large proportion of legumes and was of excellent quality. The particular lot being fed when the April samples were taken was composed of mixed grasses — a rather poor stand on a field that had not been reseeded for many years. It is regretted that carotene determinations could not have been made on these silages.

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[1] Acknowledgment is made of the cooperation of Dr. W. S. Ritchie and Dr. Wm. B. Esselen, who carried on this part of the work.

Flavor of the Milk

The same composite samples used for fat test and vitamin A assay were tested for flavor by impartial experts[1] who did not know the identity of the samples. They reported as follows:

Date	*Ration*	*Score*[1]	*Remarks*
12/14/37	Corn silage	22.5	Slight feed flavors
	Grass silage	22.5	Milks better than average in flavor
1/18/38	Corn silage	21.0	Feed flavor, flat
	Grass silage	21.5	Feed flavor
3/23/38	Dry hay	21.0	Feed flavor
	Grass silage	22.5	Slight feed flavor
4/15/38	Dry hay	21.0	Slightly acid
	Grass silage	23.0	

[1] 25 is considered a perfect score.

These results show that, except for the December samples, for which the scores were identical, in the opinion of these judges the milk from cows receiving grass silage was superior in flavor to that from cows receiving the other feeds. In view of the results set forth in the preceding section on vitamin A content of the milk and the generally recognized relationship between vitamin A and milk flavor, these results are not surprising.

Costs of Making Grass and Legume Silage

Costs vary so from place to place and from year to year that no hard and fast set of figures can be given with the expectation that they will be generally applicable. From the records that have been kept at the State College, from costs published by other institutions, and from unpublished information furnished by several operators in this State, it seems that the cost of grass silage in an average season may be higher than for a similar amount of dry matter stored as hay, but the difference will not be great. In an unfavorable haying season, the grass silage possibly would be cheaper than hay and would have the further advantage of higher feeding value per unit of dry matter. Usually it will be cheaper than corn silage for two reasons: (1) Land must be prepared for corn each year and weeds have to be kept down, while grass land is usually plowed not oftener than once in three or four years; (2) investment in special machinery will be less.

The following itemized costs are taken from the State College records. It is fully realized that they are higher than would be the case on efficiently operated, privately owned farms, but they may serve as an indication of what to expect in the way of maximum cost of such material.

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[1] Acknowledgment is made of the cooperation of Professors H. G. Lindquist and M. J. Mack, who judged the flavor of the various samples.

	Cost per ton of grass silage fed out
Fertilizer and manure	$0.82
Seed	0.12
Labor of preparing and seeding the land	1.04
Labor of harvesting and filling the silo	2.37
Molasses	.78
Total	$5.13

It should be noted that these figures are for silage actually fed out; i. e., after all losses have been deducted. Persons attempting a comparison with hay or corn silage should bear in mind that there are considerable losses from these also. Hay is subject to considerable loss in the harvesting process due to shattering of leaves and to leaching if rained upon, and it undergoes further losses as a result of the sweating process in the mow. Some people erroneously believe that the loss in the mow is only water. Generally speaking, only about half of it is water, the rest representing valuable feed nutrients, and the damper the hay is when it goes in, the higher is the loss of these.

Corn, while it undergoes very little loss in the harvesting process, is subject to the same fermentation and seepage losses as grass silage.

Practical Considerations

In conclusion, it must be emphasized that the method is not a magic formula for making good feed out of poor roughage. The man who puts poor quality, overripe grass or legumes into the silo with the idea that it will come out a high-grade feed is doomed to disappointment, as is also the operator who is careless with the details of the process or who uses a silo that is not tight.

The process is not expected to supplant ordinary haymaking, but rather to supplement it, making the farmer more independent of the weather, enabling him to plan his seasonal operations more effectively and to avoid the large losses experienced during such haying seasons as those of 1937 and 1938.

Places where it will fit in to best advantage are:

1. For late summer feed, to take the place of short pastures, especially during the dry spells so often experienced in July and August. Used for this purpose, one silo will serve for both corn and grass. If the grass silage is not all fed out when corn cutting time arrives, no harm is done for the corn can be blown right in on top of it.

2. On farms where the land is not well suited to the growing of corn, such as heavy, wet bottom lands which, in some seasons, cannot be prepared for corn until it is too late, but which will produce a heavy yield of grass year after year with no extra labor except that of top-dressing with either manure or fertilizer.

It is perhaps needless to point out that the growing of grass or legumes and the storing of part of the crop as silage ties in much better with any program of soil conservation and erosion control than does the growing of an annual cultivated crop like corn. The argument usually offered in favor of corn is that a much larger tonnage of feed per acre can be grown than is the case with a hay crop. This argument is not as valid as it was at one time for two reasons: (1) The earlier date for the first cutting of grass when it is to be stored as silage, means a larger crop of rowen. Under some conditions and with certain crops a third cutting is now possible where formerly it was not. (2) The great reduction in the price of nitrogenous fertilizer has made possible a total seasonal tonnage from such a crop as timothy, which is comparable with average corn yields, and which contains a somewhat higher percentage of protein than either corn or unfertilized grass.

Phosphoric Acid Silage

This method of preserving silage has already been referred to and the principle upon which it depends has been explained. (See page 3). Our first experience with it at the State College has been during the present season. Somewhat over 100 tons of phosphoric acid silage made from grass were stored last June. The silo was opened the middle of November and at date of writing (January 1939) the material is being compared with corn silage for milk production. Later in the winter it will be compared with molasses grass silage, and results of the trials should be available early in May.

Details of harvesting and filling are the same as for molasses silage, except that a much smaller amount of phosphoric acid is required. Amounts recommended are:

	Per ton of green crop
For grass	10 pounds
For legumes	17 pounds

These amounts are for commercial acid of 68 percent strength (48.7 degrees Beaume). Acid of greater or less concentration would be required in proportionally smaller or larger amounts.

Although it is possible to add the acid undiluted from the cask, it is now recommended to dilute it at the rate of 1 part of acid to 5 parts of water by volume. The acid is shipped in wooden casks, and although not nearly so corrosive as either sulfuric or muriatic acid, it should be handled in wooden pails and dispensed with a wooden spigot such as is used on a cider or vinegar barrel. The cutter and blower should be thoroughly flushed with a hose after the job is finished and between times if there is a lay-off longer than overnight.

Phosphoric acid is easier to regulate than molasses in adjusting flow. It flows more freely and is cleaner. At its present price, it is slightly more expensive than molasses despite the much smaller amount used; but as demand for the particular grade used for silage increases, quantity production may bring the price down to a level where it will compete actively with molasses.

When purchasing phosphoric acid for this purpose, care should be exercised to obtain a grade that contains only very small amounts of fluorine. The element fluorine, when present in any considerable amount in the feed, is injurious to cattle. A large amount of work has been done on this problem and a standard for fluorine has been established. To be acceptable for silage making, phosphoric acid should contain not more than 100 parts of fluorine per million of acid, or expressed on a percentage basis, 0.01 percent.

Chemical studies of this type of silage as contrasted with molasses silage will not be completed for several months, nor will data as to losses in the silo be available until all the silage has been fed out; but superficial examination indicates that the phosphoric acid is as good a preservative as molasses.

The cattle do not eat the phosphoric acid silage quite as readily as they do the molasses silage. One or two cows consistently refuse from half to all of their daily allowance. Further results than this are not now available.

Summary

The ensiling of grasses and legumes has reached the practical stage and is being adopted by an increasing number of farmers. For the present, the use of molasses as a preservative seems to be the most economical method of making silage from these crops, although phosphoric acid may also be used for this purpose.

Any of the annual or perennial grasses or legumes, or the small grains, may be successfully ensiled, provided they are cut at the *proper stage of maturity*. The best time for first cutting for ensilage in this region seems to be the first two weeks in June.

The moisture content of the plants should be between 60 and 75 percent, which is the average range for grasses and most legumes cut at early bloom and not allowed to wilt before chopping. Very succulent legumes or grass wet with rain may run as high as 80 percent water. Grass wet with rain should be allowed to dry somewhat before cutting, and very succulent crops should be allowed to wilt in the swath before loading.

The amount of molasses required depends on the crop. Recommended amounts vary from 40 pounds per ton of green weight for grasses and small grains to 60 pounds for mixed grass and clover, and 75-80 pounds for clover, alfalfa, and other legumes.

Silage from either grasses or legumes is usually higher in protein, fiber, and minerals, and lower in carbohydrates than corn silage.

Feeding practice is similar to that for corn silage, but large amounts of legume silage should not be fed at first to cows unaccustomed to it.

Legume silage is fully as palatable to cows as corn silage. Grass silage may not be quite so readily eaten, but as a general rule is cleaned up without waste. Young cattle seem to relish it as well as they do corn silage.

Probably this type of silage cannot be fed to the entire exclusion of dry hay. When both are fed, cows seem to clean up their allowance better if the silage is fed at one time of day and the hay at another.

Feeding trials in the Massachusetts State College herd show grass silage to be equal to corn silage and superior to dry hay for milk production. Cows gained more weight on it than they did on dry hay. The fat test of the milk was not significantly different on grass silage and corn silage, but there was somewhat more difference in favor of the grass silage when it was compared with dry hay.

Vitamin A content of the milk was considerably higher when the cows received grass or legume silage than when they received dry hay, and the flavor of the milk was also superior.

The rather limited data available indicate that, per unit of dry substance fed out, the cost of producing grass silage is not much different from the cost of growing and harvesting hay — it may be more or less, depending on the season. The fact that grass silage has proved somewhat superior to dry hay for milk production will offset to a considerable extent any cost differences which may favor hay. Grass silage will generally be less expensive than corn silage.

Too much should not be expected of this system of storing fodder. It will not make good feed out of poor or overripe hay. It is of definite value in our farming system, but it is doubtful whether it will or should replace ordinary haymaking entirely. It will be of most value for late summer feed when pastures are short, and on heavy, low-lying land better suited to grass than to corn.

The growing of grass or legumes and storage of part of the crop as silage fits into any program of soil erosion control much better than does the growing of an annual cultivated crop like corn. Moreover, the tonnage of feed that such crops will produce under proper management is comparable to that secured from average corn yields.

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AGRICULTURAL EXPERIMENT STATION

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Milk Cartage in the Southwick-Agawam Area of the Springfield Milkshed

By Alfred A. Brown and J. Elizabeth Donley

Cartage rates are a fundamental factor in any program for stabilizing the fluid milk market. This study analyzes these rates in the Southwick-Agawam section of the Springfield milkshed for 1935 and suggests ways of minimizing the present inequities.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

MILK CARTAGE IN THE SOUTHWICK–AGAWAM AREA OF THE SPRINGFIELD MILKSHED[1]

By Alfred A. Brown, Assistant Research Professor, and J. Elizabeth Donley, Research Assistant, in Agricultural Economics and Farm Management.

Prior even to the widespread participation by the States and the Federal Government in the marketing of fluid milk, duplication of collection routes placed an unnecessary burden of increased costs on everyone connected with the industry. An immediate appreciation of the importance of milk cartage has arisen, however, from the attempts of Milk Control Agencies to stabilize the markets for fluid milk by arbitrarily determining Class I prices.[2] The absence of standardized cartage rates has not infrequently tended to defeat the purpose of control; namely, uniform f. o. b. the market prices.

An analysis of milk cartage is simplified if two aspects of it are promptly recognized: the physical service of moving milk from farm to plant and the rates charged for providing the service. Each is sufficiently independent to warrant separate consideration.

The requirements of an adequate cartage service are few. The principal one, probably, is that it shall move the supply from farm to city plant with a minimum change in quality. Supplementary considerations are that the service shall not interfere seriously with the dairy farmers' organization of work or with the efficient operation of the milk plant. Since the essentials are physical, they are possible of achievement for an individual or for an entire shed.

Payments for service should be provided for by a sound rate structure of which the principal consideration is that it shall be sufficient to maintain the service. In addition the rates should be equitable and simple. A workable rate structure by its very nature is arbitrary. This characteristic should be kept in mind because it is fundamental to an understanding of rates.

A sound structure; i. e., a logical geographical pattern of cartage rates, is fundamental to a stable milk industry which establishes prices on an artificial basis. Rates which are in excess of payment for cartage may become price discounts to the trade instead of accumulating as profits. Some of this can never be eliminated, even with standard rates, so long as transportation remains a dealer function. The more efficiently operated routes will show a profit which merely becomes income from another source.

The necessity for using an arbitrary rate basis should become evident upon consideration of the various ways by which rates may be set.

A common method of establishing rates and one in current use is to charge what the traffic will bear. In practical operation, this principle provides for charging as high a rate as possible and yet retaining the traffic. Retention of milk traffic in a trucking area is contingent not so much on cartage rates as on alternative market outlets available to producers. The prices paid for milk f. o. b. the market vary among the dealers. It is possible to reduce the differences by compensating variations in trucking charges so that the farm prices tend to be uniform. Hence the upper limits of what the traffic will bear depend first on relative net prices and secondly on whether or not a dealer's nearest, most favorably situated competitor cares to take on additional patrons.

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[1] This report is part of a general study of milk marketing in the Springfield Milkshed. Acknowledgement is made of the helpful assistance given by dairymen, distributors, local health offices, the Massachusetts Milk Control Board, and the Milk Administration of the State of Connecticut.

[2] Some agencies determine prices for milk in other uses; all, however, regulate at least the Class I price.

A rate structure based on "cost of performing the service" invites confusion. Cost records undoubtedly may be useful as a guide in establishing rates. Difficulties in all probability would ensue should cost records be given a more direct usage. Possible dangers are suggested in an attempt to define "cost of performing service." Is average cost meant and if average, which one? Is that cost meant which is incurred by the most efficient carrier? Should the cost of performing the service be determined for each route and separate rates established? To use this method would result in a situation no better than the present.

Cost cannot be ignored. It must be considered, however, from the viewpoint of the industry. Competition among carriers to provide the service should be a satisfactory indication of the adequacy of the rate level in meeting costs on the basis of the volume moved.

A number of physical factors could have a bearing on the rate which shippers should pay for transportation service. Among them are: (1) distance from market, (2) size of shipment, (3) percentage of Class II in shipment, (4) quality of product, (5) location of farm, (6) regularity of shipment. Each of these factors has a definite effect on the efficiency of operating the transportation service. No rate structure yet exists which takes all of them or even the majority of them into consideration. Nor is there reason to believe that a rate structure giving due weight to each of these factors would be sufficiently satisfactory to warrant its application. The use of these factors, jointly or in part, imposes the necessity for making an arbitrary decision. For example: shall "distance" be distance from the market "as the crow flies," over the most direct road, or over the route taken by some trucker? It should be evident that the application of a mileage scale to distance as measured along a given route places a premium on one end of the route. Furthermore, once the truck gets into "pick-up" territory, load volume may increase at a more rapid rate than route mileage, in which event the cartage rate per mile should perhaps be on a decreasing scale. Obviously, minute adjustments of this type would involve tremendous detail and are unnecessary.

The requirements of sound rate structure can be met by giving due observance to its objectives, which were established as:

1. Maintenance of service
2. Equity to all within the industry
3. Simplicity

Maintenance of service can be assured by a flexible rate structure permitting adjustments in the level of rates. Equity can be assured within reasonable limits by the application of uniform rates for equivalent service. Simplicity can be achieved by using a little common sense in applying the different factors which might have a bearing on the rate paid.

SUPPLY CHARACTERISTICS OF THE SECTION

The cartage service operated in the Southwick, Agawam, Suffield, Granby section is influenced by the nature of the supply and of the outlets.

In the towns of this section, 736 farms reported cows and heifers milked in 1934, according to the 1935 U. S. Census. This figure is reasonably accurate for 1935. At some time or other in 1935, 133 of these farms sold milk at wholesale in the Springfield marketing area. Obviously variations occurred during the year: producers coming into the market for the first time, producers dropping out of the market, producers changing from wholesale to retail selling, and producers shifting from retail to wholesale selling. In January 1935, 119 producers were selling milk at wholesale in the area; in May, 105; and in December, 96.

That only 18 percent of the dairy farms in the section are recorded as having sold milk in the marketing area is no unfavorable reflection on the adequacy of the data. The Connecticut farms included in the group are a negligible proportion of the total in the Connecticut towns, being only 4.3 percent. Most of the farms selling milk in these towns contract, in all probability, with Hartford or local dealers. Of the Massachusetts farms, 38.7 percent sold in the Springfield area. The balance of the farms probably kept a cow or two to supply the farm needs and sold little or no milk. Two general factors lead to this conclusion.

The first is the very noticeable variation among the three Massachusetts towns in the proportion of farms recorded as selling milk, and the second is the average number of cows per farm in these towns. The detailed relationships are shown in Table 1. Of the three towns it is evident that Southwick is the dairy town. Agawam, adjacent to the river, is a crop farming area and probably the home of part-time farmers with occupations in Springfield. Both of these factors would be conducive to family cows rather than commercial herds. Southwick, to the west, although a crop farming town, is rolling country, very suitable to grass and forage crops and cows. An indication of the commercial importance of dairying in Southwick is the proportion of farms selling milk and the relatively high number of cows per farm. Practically 60 percent of the farms sold milk in the area and the average number of cows milked per farm was eight. Granville, to the west beyond Southwick, is a New England hill town. Natural conditions would tend to keep the number and size of dairy herds low. The small proportion of these farms recorded as selling milk in the Springfield area is due in part to the fact that no data were available on some of them, and in part to the fact that many of the cows were undoubtedly kept to supply home requirements. Granville, it might be noted, had the smallest number of cows and heifers per farm.

TABLE 1.— NUMBER AND PERCENTAGE OF DAIRY FARMS IN THE SECTION, SHIPPING MILK TO THE SPRINGFIELD MARKET AREA, 1935.

Town	Number of Farms Reporting Cows and Heifers*	Number of Cows per Farm	Number of Farms Shipping to Springfield		Percentage of Farms Shipping to Total Farms
			1935 Maximum	January 1935	
CONNECTICUT					
Granby..........	143	7.7	4	2	2.8
Suffield..........	299	6.5	15	13	5.0
Total..........	442		19	15	4.3
MASSACHUSETTS					
Agawam.........	133	4.4	41	37	30.8
Granville.........	67	3.8	15	13	22.3
Southwick........	94	8.1	56	52	59.5
Total..........	294		112	102	38.1
Unknown..................................			2	2	
Section Total.......	736	6.2	133	119	18.1

*U. S. Census, 1935.

Location of Farms

Since all the farms[3] throughout the section received farmstead service in 1935, the importance of road type is minimized so far as the milk cartage is concerned. Factors in addition to road surface are probably responsible for the absence of dairying in those towns in which it is relatively unimportant.

Of the recorded farms in the section, 58 percent are located on or within a mile of main-traveled highways. Many of the others are just beyond this band. A sufficient number of farms lay scattered at outlying distances so that it was necessary for truckmen to drive on all types of road to provide a complete pick-up service.

The significance of farm location in relation to cartage service cannot be overemphasized. Farmers living at a distance from improved roads might be expected to enjoy year-round farmstead service, rarely if ever, even though they were willing to pay a substantially higher trucking charge than other producers on the route.

The carriers are also interested in another aspect of farm location. Routes on which farms are spaced relatively near one another have the possibility of being more profitable sources of traffic than routes on which the same sized farms are spaced far apart with the intervals largely rocky, untillable terrain or woodlot.

Figure 1 shows the location of practically all farms in the section shipping to dealers in the Springfield market area. Farms situated within one mile of a surfaced highway were considered as being on-route; those beyond that band as being off-route. The use of a two-mile band — one mile strip on either side of the main highway — was determined by several considerations. Side roads tend to be better surfaced and cared for, the nearer they are to the main thoroughfare. Carriers might be expected to offer farmstead service to farms on the improved part of the road at no great distance from the surfaced highways. The first zone of a proposed rate structure has a one-mile radius and the use of a band one mile on each side of the through roads was considered consistent.

Location, determined as previously described, had no influence on cartage rates. A different cartage rate was in force on each route, yet on any particular route, except one, all producers paid the same rate. On the single route having varying rates for different producers, a smaller proportion of producers off-route paid higher rates than those on-route.

The relationship between location and ratio of deliveries to rating requires additional study. Of the 12 producers with ratings[4] and satisfactory records to study, 8 were off-route. Sixty percent of the producers whose deliveries were approximately equal to their ratings were off-route, but all of the producers whose deliveries were 150 percent or more of ratings were off-route. With so small a number of producers, no definite conclusions are possible. The indicated possibilities should be considered in terms of a larger group.

A greater proportion of producers off-route had higher average daily deliveries than did the section as a whole. The modal class in both instances was identical, 90-119 pounds per day, and the percentage in the modal class in both groups was approximately the same, 22.9 percent for the off-route producers and 20 percent for the section. The off-route producers had 16 percent of their group below the modal class — a much smaller percentage than the entire section, which had 30 percent below the 90-119 pound class.

Quality indications are confined almost exclusively to butterfat variations.

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[3] All farms on which data could be secured.

[4] A specified daily quantity of milk which a dealer agrees to buy from a producer.

Only two producers in the section were paid on a Grade A basis. Both of them were on-route.

A record of butterfat tests was available for 105 producers in the section, 38 of whom were off-route. No butterfat records were available in 33 cases, 10 of them off-route producers. Practically all of the lots for which no test was available were paid for on a flat plan basis. The percentage of producer deliveries with no recorded test was about the same for the off-route group as for the section, 20.8 and 23.9 respectively. The only noticeable differences between the butterfat test for all producers in the section and for the off-route group were the limits of the modal class and the percentage of lots below it. The modal class for butterfat test throughout the section was 3.75–3.99, with 30 producers in the class, representing deliveries of 31.4 percent of all producers. For the off-route group the modal class was 3.5–3.74, with 14 producers or 36.8 percent of the group. The percentage of producers below the modal class was much higher for the section (30.4) than for the off-route group (13.1). The off-route producers apparently had cows producing lower testing milk than the section as a whole.

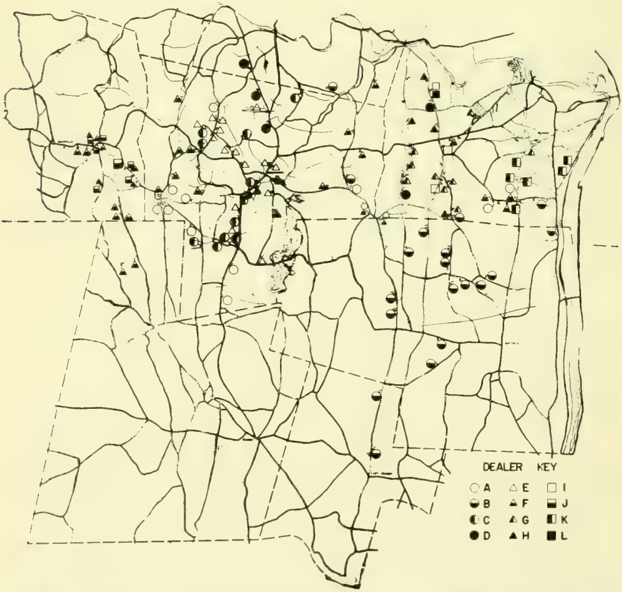

Figure 1. Location of Farms Shipping Milk to Dealers in the Springfield Market Area.

Markets of Wholesale Producers

Producers in the section, for all practical purposes, sell in one market — the Springfield, Holyoke, and Chicopee area. Distribution activities so generally radiate from the plant to near-by towns that a number of towns and cities comprise the general market. Figure 2 shows some of the towns in which the various distributors were licensed to sell milk. All dealers to whom producers delivered milk were licensed to sell in Springfield. All but one of them, a small dealer, sold in at least one other town. It is worth noting that, although only one of the dealers with plants in Springfield was licensed in Westfield, two resident Westfield dealers sold in Springfield.

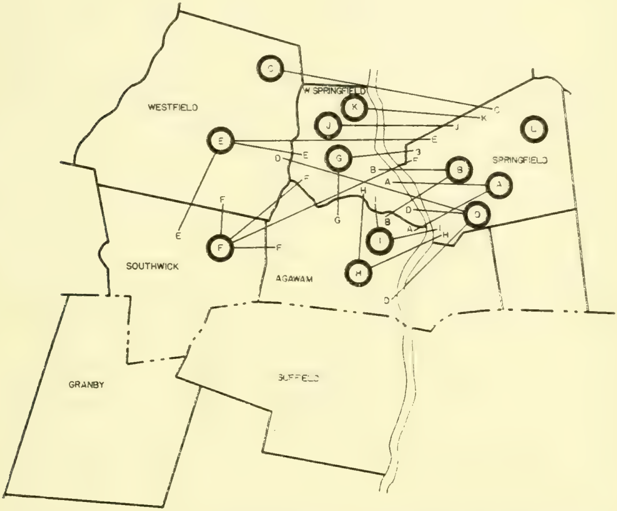

Figure 2. Cities and Towns in Which Buyers (i. e., Milk Dealers in the Market Area) Were Licensed to Sell Milk.

The general market area contained and controlled the individual dealer markets used by producers. Dealer plants receiving milk from farmers in the section were widely distributed throughout the market area. Two were located in Westfield,[5] one in Southwick, two in Agawam, three in West Springfield, and four in Springfield. There was in addition another plant at Westfield but the records were incomplete and generally not usable.

Five of the plants secured their total requirements from the section. They were with one exception small, ranging from 344 to 3,064 pounds daily in January 1935. The remaining plants drew only a part of their supplies from this section, which for some of the plants was substantial whereas for others it was infinitesimal. Although these plants were outlets for all of the milk in the section, its share of the markets' requirements ranged from only 7 to 10 percent during the year.

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[5] Data were not available on all Westfield dealers at the time data were collected.

CARTAGE SERVICE IN THE SECTION

Routes Operated

Twelve dealers purchased milk in the section during January 1935. A separate collection route served the shippers of each distributor. Eight of the routes were operated by the dealer, two by contract carriers, and two by producer-truckers. Only one change occurred in the number of routes operated during the year: one dealer dropped his producers and gave up the route "because the supply was too far from his plant."

The average daily volume trucked out of the section in January 1935 was 15,703 pounds. The size of loads ranged from 344 to 3,064 pounds. The total number of producers shipping was 112 and the number per load ranged from 2 to 28. The volume per load and number of producers per load are shown in Table 2.

TABLE 2.— AVERAGE DAILY VOLUME HANDLED, PRODUCERS SERVED, AND DEALERS RECEIVING MILK BY ORIGINAL AND REORGANIZED ROUTES January 1935

Original Routes				Reorganized Routes			
Route	Volume (Pounds)	Producers	Dealers	Route	Volume (Pounds)	Producers	Dealers
A	1,779	10	1	Westfield	3,035	23	2
B	2,144	16	1	West Route	3,159	30	3
C	1,114	11	1	East Route	6,201	44	8
D	2,144	5	1	D	2,144	5	1
E	1,759	14	1				
F	3,064	28	1	Truck own	221	3	2
G	733	7	1				
H	552	3	1	Producers			
I	727	3	1	unlocated	943	7	3
J	872	8	1				
K	471	5	1				
L	344	2	1				
Totals	15,703	112	12		15,703	112	

Variations in the size of the load from month to month are of especial significance to the carrier and of some significance to the producer. The facilities provided by the carrier are dependent on the maximum daily load delivered by the producers on the route. Extreme variation in deliveries by patrons means much unused truck capacity during a large part of the year, even though overloading may be practiced during the period of heavy shipments. The cost of maintaining peak-load equipment must be met either in terms of higher cartage rates to producers or lower net income to carriers.

Figure 3 shows clearly for a two-year period the seasonal variation in milk load on nine routes operating out of the section. The routes of the flat price plan dealers show no practical variation. Their loads are also very small. Three of the remaining routes do not show too wide variation in loads, whereas the last three, B, D and F, show marked change with an apparent trend.

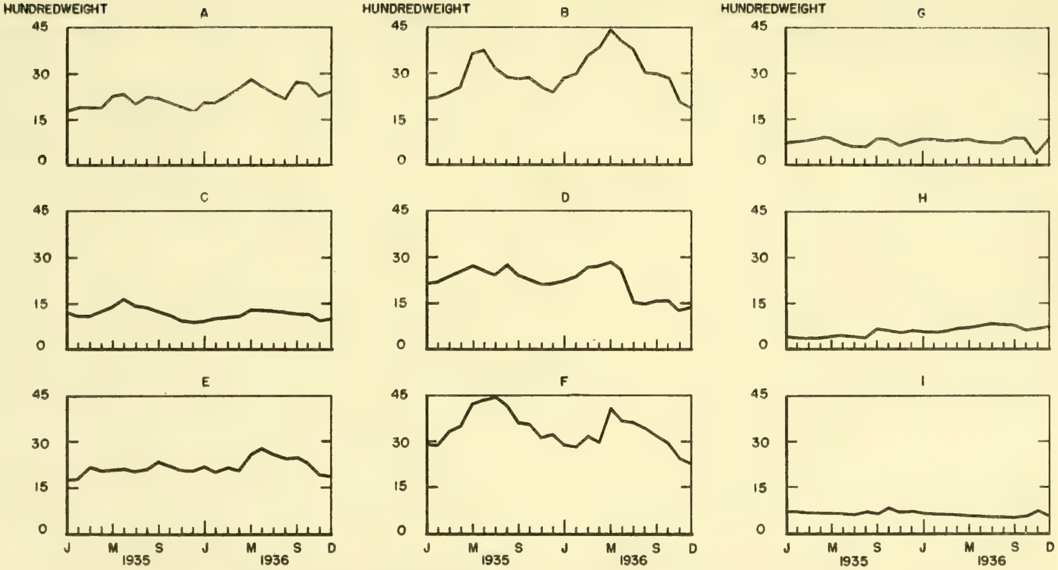

Figure 3. Average Daily Load of Milk on Truck Routes in the Southwick-Agawam Area.

The seasonality of milk loads also reflects seasonality of production in the section on the farms of producer groups serving the various dealers. The charts also indicate the relative importance of the various dealers in the section at different times during the two-year period. The trend indications are due chiefly to a shifting of producers among dealers.

Efficiency of Transportation

All units in the industry have an interest in the efficiency of milk transportation. The carrier is concerned with the profitability of the enterprise. The producer is concerned with the cash cost of the service. The dealer is concerned with the relationship between the cost of the service and the cost of his product delivered at the plant.

The same physical items that tend to assure a profitable milk trucking business provide the basis for a low-cost transportation service. Among these factors are size of load, total mileage traveled, collection miles traveled, and number of stops, which may or may not be identical with the number of producers served.

Detailed presentation of these items for all but the smallest routes is given in Tables 3 and 4. Since the data were on a monthly basis, it was not possible to determine the day of highest or of lowest loadings. The nearest approach to this was a calculation of the highest average daily loadings and of lowest average daily loadings, which occurred in May and December respectively. The purchase plan and business management probably had as much to do with the variation in size of loads as any single factor.

TABLE 3.— PHYSICAL FACTORS AFFECTING EFFICIENCY OF TRANSPORTATION*
May and December 1935
(By cartage routes)

Route	Load (Pounds)		Stops per Load		Pounds per Stop		Total Miles Traveled		Collection Miles Traveled		Percentage of Collection Miles to Total Miles	
	May	Dec.	May	Dec.	May	Dec.	May	Dec.	May	Dec.	May	Dec.
A	2,228	1,463	10	9	222	162	47	45	23.5	18.0	50.0	40.0
B	4,293	2,508	19	18	225	139	45	45	33.3	27.0	74.0	60.0
C	1,196	890	9	9	132	98	22	22	14.0	14.0	63.4	63.4
D	2,683	2,161	5	5	537	432	26	26	12.3	12.3	47.6	47.6
E	2,231	1,543	14	12	159	128	23	23	9.3	9.3	40.8	40.8
F	5,362	3,224	32	27	167	119	45	38	41.0	34.5	91.0	91.0
G	818	775	5	6	163	129	13	13	9.7	9.7	75.3	75.3

*Average daily basis.

Flat price plan dealers tend to purchase close to fluid requirements; consequently their average daily loads tend to be relatively stable barring losses in sales. Routes G, H, and I in Figure 3 bear this out. The rating plan as used by some dealers encourages fairly even deliveries. Route D (Figure 3) is an indication of this. Seasonal variation in the size of other loads is due mostly to variations in average daily deliveries of producers.

Data in Table 3, supplemented by the charts in Figure 3, should show emphatically that during only brief periods of the year could truck facilities and load carried have been the same. It is not necessary to know the capacity of the trucks to appreciate that either overloading or underloading was general throughout most of the year. Even though producers may be indifferent towards this situation, the carriers cannot be, because the result is reflected in the cost of providing the service.

In a study of collection routes in Maine,[6] it was found that size of load was definitely associated with the distance traveled by the truck. This relationship exists in this section of the Springfield shed, particularly as between collection mileage[7] and volume rather than total mileage and volume.

Just as there is a positive relationship between distance and volume, so is there a positive relationship between density[8] of milk traffic and size of load. No route in the section had the desirable combination of both of these factors. The routes having a high density of traffic were low on collection miles. The relationships are shown in Table 4.

TABLE 4.— EFFICIENCY OF MILK CARTAGE AS DETERMINED BY RELATIONSHIP OF SELECTED PHYSICAL FACTORS
May and December 1935

Route	Pounds of Milk per Mile, based on—				Miles Traveled per Stop, based on—			
	Total Milage		Collection Mileage		Total Mileage		Collection Mileage	
	May	Dec.	May	Dec.	May	Dec.	May	Dec.
A	47	32	94	81	4.7	5.0	2.3	2.0
B	95	55	128	92	2.3	2.5	1.7	1.5
C	54	40	85	63	2.4	2.4	1.6	1.6
D	103	83	219	177	5.2	5.2	2.4	2.4
E	97	67	234	162	1.6	1.9	.66	.78
F	119	84	130	93	1.4	1.4	1.2	1.2
G	62	60	83	79	2.6	2.2	1.9	1.9

The relationship between collection mileage and total mileage deserves consideration. A high percentage of collection miles to total miles traveled means little unless the density of traffic (pounds per collection mile) is heavy. Truck travel in non-pick-up territory may of itself produce no income, but it may be supplementary to collection operations in a heavy producing area. From the viewpoint of the individual route operator a certain amount of deadheading[9] may be preferable to an increase in collection mileage if such increase is in low-producing territory.

It would seem to be in the interest of the industry to reduce deadheading to a minimum. If the industry accepts the principle that all milk in the section should move to market, there is little to justify certain routes taking only that part of the section having low volume per mile traveled. That service so provided increases the cost of the product laid down at the distributors' plants hardly needs emphasizing. Routes organized to collect milk with the minimum of deadheading could not expect the density of traffic now enjoyed by the best routes in the section, but they would develop a volume substantially heavier than the bulk of those now operating.

The influence of traffic density is shown by the cumulative loading charts in Figure 4. Charts A, E, and F show the volume of milk on selected routes for January 1935 and include the one with the heaviest load, the one with the highest density, and one with fair volume and intermediate density. The charts also indicate the density of traffic along the route; a flattening out being due to a

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[6] Dow, G. F. Costs and returns in operating milk and cream collection routes in Maine. Maine Agr. Expt. Sta. Bul. 374, 1934.

[7] Distance between first pick-up and last pick-up.

[8] Pounds of milk per collection mile.

[9] Truck travel in non-pick-up territory, i.e. from plant to first farm and last farm to plant.

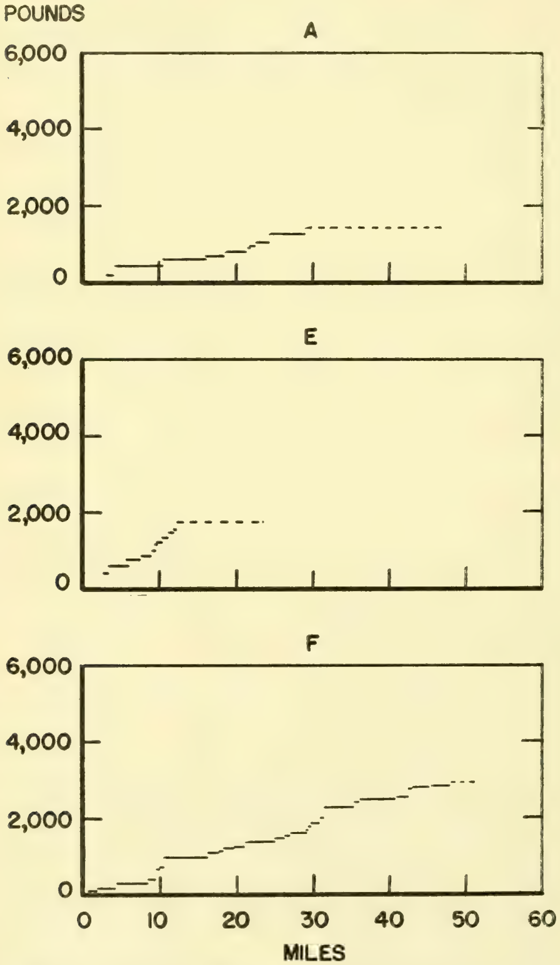

Figure 4a. Cumulative Loading on Selected Original Routes, January 1935.

reduction in volume relative to distance. Good routes, distance considered, will show curves rising sharply upward; poorer routes will have relatively flat curves.

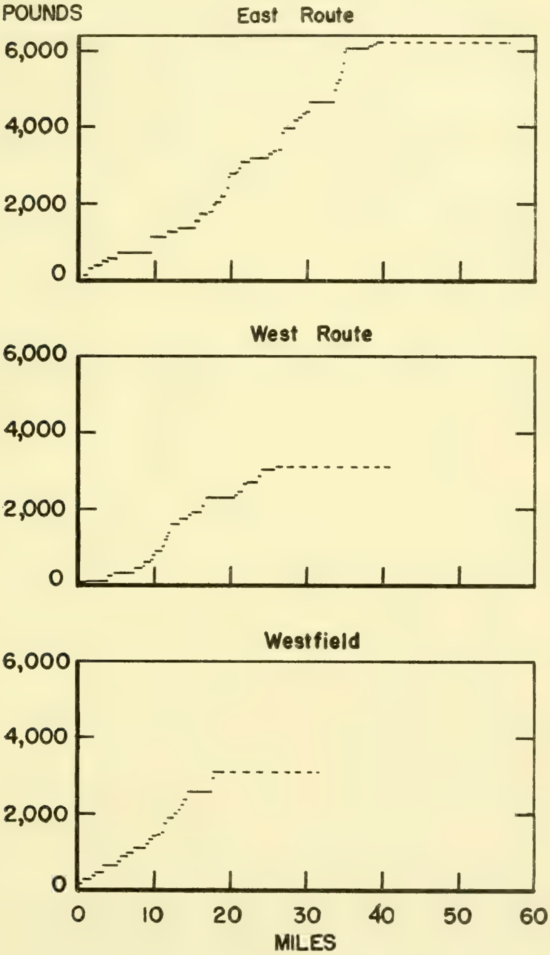

Figure 4b. Cumulative Loading on Suggested Routes, January 1935.

Trucking Rates

Few products, farm or industrial, show as much variation in the prevailing rates for transportation as milk. That this situation can exist is due entirely to the characteristics of the industry. No business other than milk has so close a relationship between the buyer or seller and the carrier. In many instances the carrier is either buyer or seller. Under such conditions, the net profit from the business as a whole is the chief concern and the transportation of milk may actually be carried on at a loss, or city distribution may be conducted at no profit with cartage operations providing the principal source of income.

Certain operating problems which have been mentioned as influencing service may influence rates: wide seasonal variation in shipments, generally small individual shipments, farmstead service to shippers, the collection of all market milk in the area, and a greater supply than can be utilized by the fluid market.

Though the milk transportation service has the characteristics of a common carrier in that the service must be provided daily and at a regular time over a regular route, the convenience of service applies to each dealer rather than to the industry, with the result that the common carrier aspect at present has little bearing on rate making.

Eleven different rates were in force during the early part of 1935. The practical extremes were 20 and 46½ cents. Only one route really had a scale of rates. Several of the rates were used by two or more routes. The most common rate, from the viewpoint both of the dealers using it and the producers to whom it applied, was 35 cents per hundredweight. Table 5 shows the picture in detail.

TABLE 5.— RATES PAID PER ROUTE, 1935

Rate	Number of Routes	Total Producers	Number of Producers per Route											
			A	B	C	D	E	F	G	H	I	J	K	L
.20	1	5						5						
.23	1	10			10									
.25	1	4						4						
.28	2	22		18				4						
.30	3	13				4		7				2		
.33	1	9						9						
.35	4	28	13						9	3		3		
.40	1	14					14							
.44	2	1												1
.465	3	13					3				2		8	
Over .465	1	3										3		
Total		122	13	18	10	4	17	29	9	3	2	8	8	1

The causes for such a variety of rates in so small a section are in part self-explanatory. Since each route but one had a common rate applicable to all producers on the route, such items as size of average daily deliveries, butterfat test, location of farm, and distance of the farm from the plant could have had no specific bearing on the rate as applying to a particular farm. Nor were these factors responsible for the differences in rates which existed among routes. With physical factors eliminated, it must be concluded that rates were arbitrarily set.

On the single route where a scale of rates was operative, two factors seemed to be related to the trucking rate: location and distance. Each rate applied to a group of producers in a locality and to this extent exhibited a degree of consistency. The differences in group rates were in all instances but one related to distance from plant. The one exception was a group in a locality where the competitive situation was very pronounced. Size of average daily deliveries may also have had an indirect bearing on this group's enjoying the lowest rate. One shipper in the group had the highest average daily delivery of all the producers on the dealer's payroll. He may have been granted the low rate because of this volume, and the other producers in the neighborhood given the rate because the dealer saw the desirability of having a uniform rate apply among neighbors.

Since rate variation exists chiefly among routes rather than among producers on the same route, milk prices were analyzed as being possible causes for the prevailing differences. Little or no relationship existed between average net prices, whether actual or 3.7 basis, and trucking charges. The only apparent relationship is between the adjusted maximum f. o. b. price 3. 7 basis and cartage rates.

The maximum prices received by the groups paying the different trucking rates had a much narrower range than the f. o. b. prices — 14 and 27 cents per hundredweight respectively. Had trucking rates been uniform, the range in maximum net 3.7 prices would have been the same as the range in f. o. b. prices. Since the trucking rates were not uniform and the highest rate was 13 cents greater than the difference in f. o. b. prices, the range in net prices was reduced to 14 cents. The rates and prices are shown in Table 6.

TABLE 6.— ADJUSTED F. O. B. CITY PRICE, 1935

Group	Maximum 3.7 Net Price	Trucking Rate	Number of Producers*	Adjusted f. o. b. Price	Net Price Based on Standard Trucking Cost (.20)
I	$2.42	$.20	5	$2.62	$2.42
II	2.34	.23	10	2.57	2.37
III	2.30	.28	22	2.58	2.38
IV	2.32	.30	9	2.62	2.42
V	2.31	.33	9	2.64	2.44
VI	2.40	.35	28	2.75	2.55
VII	2.44	.40	14	2.84	2.64
Range	.14	.20		.27	.27

*The trucking rates of 36 records were so widely scattered that no significant grouping of data was feasible.

The lower spread in net prices would indicate a rate structure based on what the traffic will bear. The dealers paying the higher prices for the most part charged the higher rates for cartage so that producers enjoyed only part of the benefits of selling to dealers able to pay higher prices.

Transportation rates are regarded as one of the inflexible prices in the distributing system. Rigidity of this kind is usually measured over a period of years, but no analysis for a period of such duration has been made for this section. Considered solely from the standpoint of twelve months, cartage rates showed little tendency to vary.

Most rate changes probably occur when producers shift from one dealer to another. Five such shifts involving ten producers took place in 1935 in the section. All producers but two secured lower rates. The average reduction was fourteen cents; the two going to a higher rate had an average increase of ten cents (Tables 7 and 8).

Table 7.— Trucking Rates Paid by Marketing Period, 1935

Rate	Number of Producers				
	Entire Year			Part Year	Total
	Rate not Changed	Rate Changed			
		Old	New		
.00	2	2		2	6
.20	4			1	5
.23	8		1	2	10
.24	1	1		2	4
.28	18		1	4	22
.30	9			4	13
.33	7		5	2	9
.35	18		3	10	28
.40	11	1		2	14
.44	2	1		3	6
.465	2	6	1	5	13
Over .465	2			1	3
Total	84	11	11	38	133

Table 8.— Kinds of Rate Changes, 1935

	Number of Producers*	Old Rate	New Rate
Producer changed dealer.........	2	.25	.35
Do.........................	1	.40	.35
Do.........................	1	.44	.28
Do.........................	1	.465	.23
Do.........................	5	.465	.33
Total....................	10		
Dealer changed rate............	11	.40	.465
Total producers affected by change in rate......................	21		

*Producers in the market for full period.

Occasionally rate adjustments are made by a dealer, and under such conditions the effect of the change may be very pronounced to the producer and to the market. One dealer increased his cartage rate 6½ cents per hundredweight. More producers were affected by this one move than by the shifting which went on among the remaining producers and distributors in the section.

Cartage rates are rarely sufficient cause for producers to change dealers. To change dealers does not eliminate the rate, but for the most part merely puts it on another level, 10 or 15 cents higher or lower. That producers will pay a higher rate for cartage is sufficient proof that they are under the impression that despite so doing they will derive a greater net return than that currently received from their present sale arrangements.

An indication of the cash cost to dairymen of moving milk from farms to plants is shown in Tables 9 and 10. Conversely these data may be interpreted as a measure of gross income to carriers for moving the product from the country to the "city."

TABLE 9.— PRODUCERS' CASH COST OF MILK CARTAGE
Average Daily, May and December, 1935

Route	May			December		
	Number of Producers	Volume (Pounds)	Cost (Dollars)	Number of Producers	Volume (Pounds)	Cost (Dollars)
A	10	2,228	7.79	9	1,463	5.12
B	19	4,293	12.02	18	2,508	7.02
C	9	1,196	2.75	9	890	2.04
D	5	2,683	8.05	5	2,161	6.48
E	14	2,231	8.92	12	1,543	7.17
F	32	5,362	15.04	27	3,224	9.17
G	5	818	2.86	6	775	2.71
H	2	402	1.87	3	612	2.80
I	3	710	2.49	3	744	2.60
J	6	693	3.54	0		
K	6	721	3.65	5	405	1.93
L	2	364	1.69	2	364	1.69
Total	113	21,701	70.67	99	14,689	48.73
Average cost per hundredweight			.325			.331
Rate with producer-carrier volume excluded			.326			.335

TABLE 10.— AVERAGE DAILY VOLUME MOVED AT PREVAILING RATES
May and December, 1935

Rate	May				December			
	Volume (Pounds)	Cost (Dollars)	Number of Producers	Number of Dealers	Volume (Pounds)	Cost (Dollars)	Number of Producers	Number of Dealers
.00	1,615	4.57	2		1,377	4.03	2	
.20	1,170	2.24	5	1	796	1.59	5	1
.23	1,134	2.60	9	2	797	1.83	9	2
.25	562	1.40	4	1	109	.27	1	1
.28	4,744	13.24	23	2	2,780	7.78	21	2
.30	2,061	6.16	10	3	1,474	4.41	10	3
.33	2,380	7.85	13	1	1,546	5.09	12	1
.35	3,993	13.95	21	4	3,166	11.08	21	4
.40	2,231	8.92	14	1				
.44	402	1.87	2	1	612	2.80	3	1
.465	1,057	4.91	8	2	1,907	8.86	14	2
Over .465	352	2.42	2	1	125	1.00	1	1
Total	21,701	70.13	113	12*	14,689	48.74	99	12*

*Several rates applied to the same dealer.

Extreme variation of two types was present. The first and least important was the variation among routes. The second and highly significant was the marked difference between December and May costs on particular routes. Group I (Table 11), composed of three carriers serving slightly over half of the producers and carting over half the total volume of milk, had an unfavorable December-May income ratio of 61. Group II, consisting of the remaining carriers, handled somewhat less milk in May and slightly more in December than Group I. The income of Group II was higher than that of Group I in both months, and the December-May income ratio of Group II was 76.5.

The group of carriers having the least variation in size of load was for the most part charging higher rates for providing the service than the carriers operating under less favorable conditions. The sole explanation for this apparent anomaly probably lies in the volume per load. Some of the loads in Group II were relatively small and although they represented high unit costs to the producer, they probably did not provide much in the way of income to the carrier.

TABLE 11.— SEASONAL VARIATION IN INCOME AND LOAD OF MOST VARIABLE AND LEAST VARIABLE GROUPS
May and December, 1935

		Group I — High Degree of Variation (A, B, and F)	Group II — Low Degree of Variation
Trucking Income			
May	dollars	34.85	35.82
December	dollars	21.31	27.42
December-May ratio	percent	61.0	76.5
Volume			
May	pounds	11,883	9,818
December	pounds	7,195	7,494
December-May ratio	percent	60.4	76.3
Income		Percent of Total	
May		49.3	50.6
December		43.7	56.2
Volume			
May		54.7	45.3
December		48.9	51.1
Number of Producers			
May		53.0	47.0
December		54.4	45.5

The importance of cartage rates in a milk marketing system characterized by artificial prices varies with the conditions prevailing in particular markets at particular times. When total market supplies tend to be generally heavier than demand, a discriminatory rate structure among carriers enables the dealer charging the higher cartage rate to use the differential in gaining a more preferential price position than he could otherwise attain. Conversely, when the total market supplies tend to closely approximate demand over a period of time, the dealer attempting to use a higher cartage rate than his competitors is at a disadvantage in the derivation of his supply because his prices to producers are proportionately lower by the amount of his cartage differential. (It is assumed that when total market supplies approximate total demand, sufficient shifts will have taken place among producers and distributors so that the purchases of individual dealers will approximate their Class I sales and f. o. b. prices will tend to uniformity.)

The present type of service offered under a variety of rates has provided producers for the most part with adequate transportation that was and is indispensable to them. Adequate as the service has been, the cost of it to the industry has been high. Such cost may be considered strictly in terms of excessive mileage, light loads, extreme variation in load sizes, unused truck capacity and the like; or it may be regarded from a more inclusive viewpoint, and in addition to the high operating cost embrace its influence on market stability and its responsibility for extending the source of supply into poor producing areas.

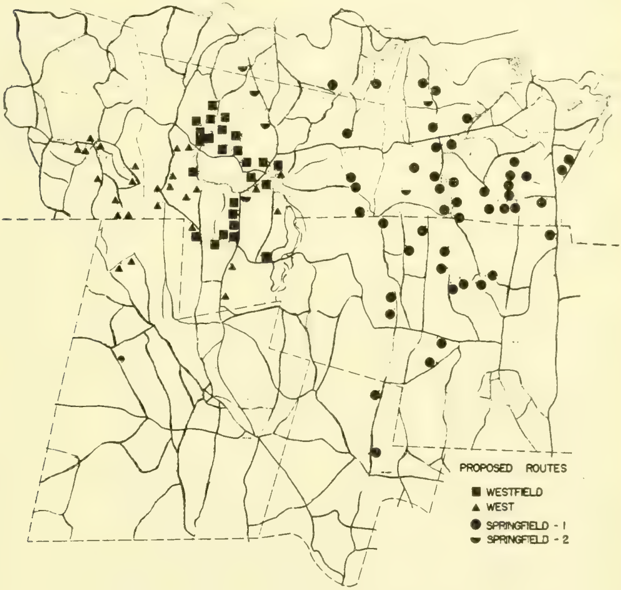

Figure 5. Allocation of Producers According to Proposed Routes.

Proposed Reorganization of Service

All members in the industry would probably welcome a more efficient cartage service. The quarter-loaded and half-loaded trucks must be discouraging to the independent carriers. The absence of standardized rates is not wholly satisfactory to producers or to dealers. Unsatisfactory as the situation may have been, improvement was scarcely possible until a way could be shown which would not interfere with relationships between producers and distributors. Accomplishment of the desired objective would be facilitated by recognition of the transportation service as an independent function. Two approaches to the problem are possible.

Either one could be used independently, although joint use would be more desirable.

Partial reorganization of existing routes might be the first approach. As a preliminary for establishing new routes, all but a very few of the producers in the section were located on maps according to dealers to whom they sold milk. Routes were determined on the basis of this information, distances traveled were calculated and checked against route reports filed with the Milk Control Board. Mileages checked within 2 or 3 percent and were regarded as sufficiently accurate for comparative purposes. New routes were then set up.

Figure 1 (page 6) shows the producers indicated according to collection routes which existed on May 1935, while Figure 5 shows producers according to proposed routes. No attempt is made to indicate on the small maps the exact routes because the situation would be confused rather than clarified.

Using data on operations as of January 1935, the original routes were compared with the proposed routes. The twelve existing routes were consolidated into four. One route operated by a producer and carrying a relatively large volume of milk was left unchanged. In order to enable a dealer to continue purchasing from one group of producers and at the same time keep non-pick-up mileage at a minimum, a transfer of milk from the west route truck to the east route truck was made at Feeding Hills.

Following this plan, total route mileage was reduced from 270 to 167. Actual collection mileage was reduced from 142 to 98. Deadheading was cut practically in half, dropping from 128 to 69. Distribution of route-mileage-use is shown in Table 12 for the actual routes and the reorganized ones. Volume per load and number of stops are given in Table 2.

TABLE 12.— DISTRIBUTION OF ROUTE MILEAGE

Route	Origin to Pick-up	Last Pick-up to Plant	Plant to Origin	First Pick-up to Last Pick-up	Total
		Original Routes			
A	3 1/4	13 3/4	3	27	47
B	4 1/8	10	3	28 1/2	45 1/2
C	0	5 1/4	8 3/4	10 3/4	24 3/4
D	0	6 1/2	13 1/8	6 7/8	26 1/2
E	5 1/2	8 1/2	0	9 3/8	23 3/8
F	3/8	3 1/2	0	43 3/4	47 5/8
G	4 1/8	3 1/4	0	9 7/8	17 1/4
J	15 3/4	16	0	6 5/8	38 3/8
Total	33 1/8	66 3/4	27 7/8	142	270 5/8
		Reorganized Routes			
C	0	5 1/2	8 3/4	17 1/2	31 3/4
East	3/4	16 3/4	0	39 3/8	56 7/8
West	1/2	3*	11	26 3/4	41 1/4
D	0	6 1/2	13 1/8	12 3/8	32
Self Haul	0	1/2	2	2 3/4	5 1/4
Total	1 1/4	32 1/4	34 7/8	98 3/4	167 1/8

*At this point the East and West Routes meet, and the load from the East Route is transferred to the West Route truck.

Route and load data on the routes for May and December are shown in Tables 3 and 13. One dealer dropped out in May. His producers were taken by other dealers but this caused no appreciable changes in individual route mileages.

TABLE 13.— A COMPARISON OF ORIGINAL AND REORGANIZED ROUTES
May and December, 1935

Route	Volume, Pounds				Mileage				Pounds per Mile			
	Original		Reorganized		Original		Reorganized		Original		Reorganized	
	May	Dec.	May	Dec.	May	Dec.	May	Dec.	May	Dec.	May	Dec.
A	2,228	1,463			47	45			42	32		
B	4,293	2,508	3,824	2,660	45	45	27	27	95	55	142	99
C	1,196	890	491*	455	22	22	6	6	54	40	41	75
D	2,683	2,161	3,653	2,570	26	26	32	32	103	83	113	80
E	2,231	1,543	2,683	2,161	23	23	26	26	97	67	103	83
F	5,362	3,224	9,594	6,415	45	38	53	52	119	84	180	123
G	818	775	1,456†	428	13	13			62	60		
H	402	612			‡	‡						
I	710	744			‡	‡						
J	693	0			38	0						
K	721	405			‡	‡						
L	364	364			‡	‡						
Totals	21,701	14,689	21,701	14,689	290	252	144	143	72	58	140	102

*Will haul own. †Not located. ‡Estimated 10 mile round trip.

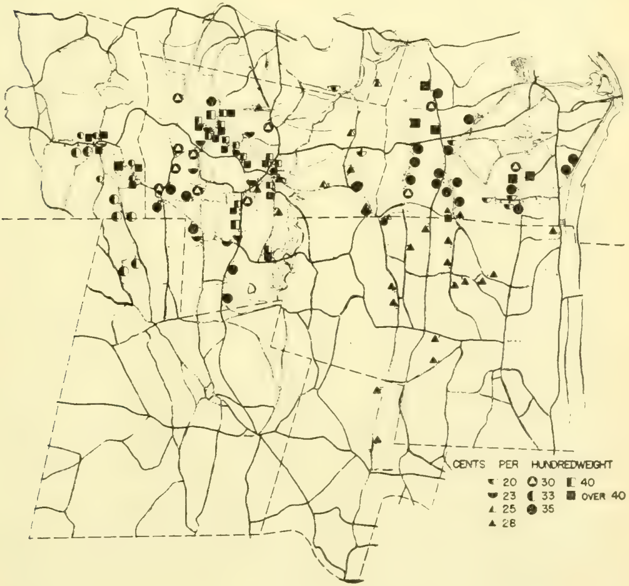

Figure 6. Distribution of Cartage Rates Throughout the Area, May 1935.

With the exception of one, all original routes were unchanged in December. One route dropped or lost a few producers so located that mileage was reduced about 20 percent. Route mileages tended to remain constant throughout the year on both the original and reorganized routes. Volume showed noticeable variations on both.

As a means of improving the present situation, route reorganization, even though only partial, is a difficult approach. Physical differences can be taken care of, but personal preferences must be left to the individual concerned. It would seem that the potential gains to both producers and distributors are sufficient to enable them to develop an efficient cartage system. The lower cartage rates which might be effective would have saved producers on the average $26.00[10] per year. (See Table 14.) This saving is not large but when added to the possible benefits of more stable marketing conditions it becomes an item worthy of consideration. The advantages to distributors from reorganized routes with standard rates may be no less than those to producers. The chief gain to the dealers would probably result from the conditions of a more stable market.

Table 14.— Average Daily Amount Producers Paid for Milk Cartage on Original and Reorganized Routes
January, 1935

Original		Reorganized*	
Route	Amount (Dollars)	Route	Amount (Dollars)
A	6.22	Westfield	6.34
B	6.00	West Route	7.88
C	2.56	East Route	15.55
D	6.43	D	5.44
E	7.03	Truck own	
F	8.39		
G	2.56		
H	2.47		
I	2.54		
J	4.05		
K	2.63		
L	1.59		
Average per hundredweight	.334	Average per hundredweight	.242

*Both routes and rates.

Should distributors and producers decide that they want a more satisfactory cartage service, transportation management details could be arranged. A transportation authority composed of distributor representatives and producer representatives could outline the service, select the carriers and negotiate the rates.

Proposed Reorganization of Rate Structure

The more effective approach towards improved milk transportation is through rates. The adequacy of this approach is substantiated by the ultimate trend to increased operating efficiency which would result. Distributors now performing their own cartage service might prefer a standard rate structure to relinquishing their direct producer contacts on a reorganized route basis. Since a standard rate structure should generally lower producer unit marketing costs, an immediate gain would be assured to one group in the industry.

---

[10] Product of difference in average rates and midpoint of modal class of average daily deliveries.

The nature of milk pricing, the relation of cartage rates to it, and the nature of the cartage service are such that cartage rates are a matter of concern to the Milk Control Board and might be to the Department of Public Utilities. It is not out of place to note that the function of the Control Board is to stabilize producer prices by establishing dealers' prices f. o. b. the market. Dealers' prices f. o. b. the market, as indicated by Cassels, Rowe and others, are made up of a combination of prices representing payment for milk and for services. It is evident that the objective of fixing f. o. b. the market prices can scarcely be achieved if the prices paid for the intervening services are seriously out of line.

A sound rate structure has but two characteristics: simplicity and flexibility. The rate structure is the basis on which rates are determined; consequently it should be easily and readily understood and sufficiently adaptable to assure fulfilling the established objectives.

The objectives of a rate structure are three. It should assure maintenance of service through establishing proper rate levels. It should be equitable, and equity can be achieved through a standard method of rate determination. It should bear some relationship to the transportation service performed.

A tentative rate structure has been devised which could be generally applied throughout the shed. Distance from market and farm location, principal operating cost factors, are the bases.

The distance principle is applied on a zone basis, zones increasing in a geometric ratio beyond the first zone. The center of the city (market) was determined as closely as possible by observation with due regard for the center of population. For plants located in towns in the market area but outside the population centers, the plant itself was taken as the center from which to determine zones. The zones and widths are given in Table 15.

TABLE 15.— PROPOSED RATE ZONES FOR THE SPRINGFIELD MILKSHED AND ZONE RATES PROPOSED FOR ON- AND OFF-ROUTE PRODUCERS

Zone	Miles		Rate per Hundredweight	
	Width of Zone	Maximum Distance	On-route	Off-route
A		2	.15	.20
B	5	7	.20	.25
C	10	17	.25	.30
D	20	37	.30	.35
E	40	77	.35	.40

Using this method of determination, all producers in the section were located no farther than Zone C from Springfield, in which city the most distant plant was located.

Rates would be calculated in arithmetic progression from a fixed minimum applicable in Zone A. The rates given in Table 15 are based on a minimum rate of 15 cents per hundredweight and a zone differential of 5 cents.

Suggested Cartage-Rate Zones for the Springfield Market Area.

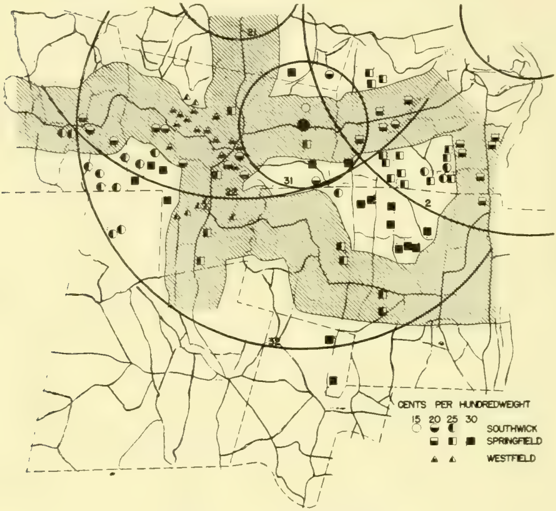
21
31
22
2
32
CENTS PER HUNDREDWEIGHT
15 20 25 30
SOUTHWICK
SPRINGFIELD
WESTFIELD

Figure 7. The Entire Section.

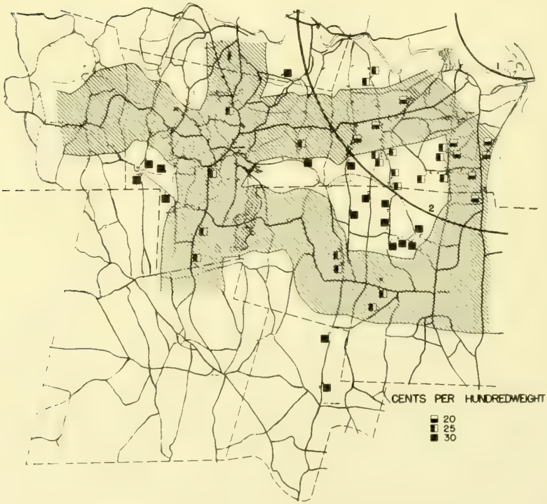
2
CENTS PER HUNDREDWEIGHT
20
25
30

Figure 7a. Springfield.

Suggested Cartage-Rate Zones for the Springfield Market Area.

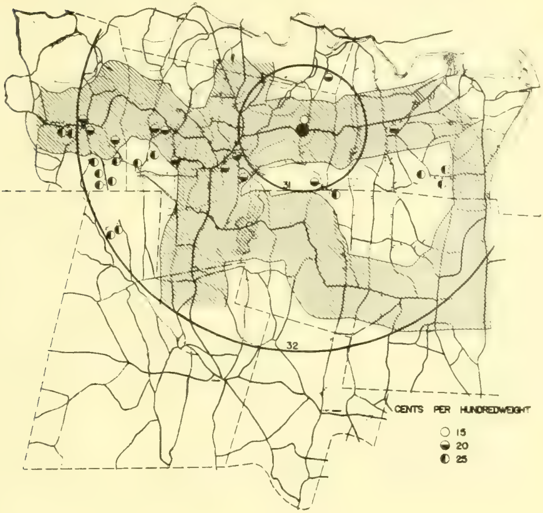
31
32
CENTS PER HUNDREDWEIGHT
○ 15
◒ 20
◐ 25

Figure 7b. Southwick.

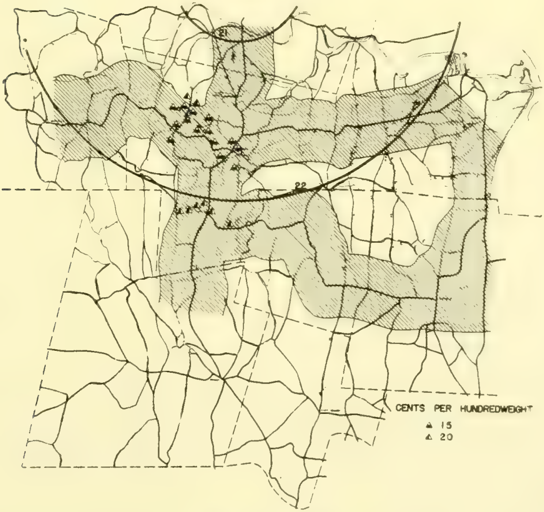
21
22
CENTS PER HUNDREDWEIGHT
▲ 15
△ 20

Figure 7c. Westfield.

The location principle is used to compensate for added distance, side trips from main roads, and inferior travel conditions of back roads. Producers are grouped as "on-route" and "off-route." Producers located within one mile of predesignated main-traveled highways are classified as on-route; all others are off-route. Off-route producers pay in addition to their zone rate a location differential which has been assumed for illustrative purposes to be 5 cents per hundredweight.

Figure 7 shows the zones for each of the three concentration points separately and combined. With the exception of a broad V-shaped part of Agawam, a shift by producers in market points would alter their rate zones and rates.

The effect of applying the suggested rates on reorganized routes is shown in Table 14. Data on daily collections as of January 1935 were used to illustrate the relationship before and after, and to calculate the average rates per hundredweight. Reorganizing the routes and establishing the rates by a standard method lowered the average rate per hundredweight slightly over 9 cents.

A frequency distribution of the proposed rates and of the existing rates is given in Table 16. The number of rates applicable was reduced from 12 to 4 and the maximum practical rate from 46.5 to 30 cents per hundredweight. The common rates were 20 and 25 cents. The relative importance of these two rates would probably remain the same when the producers currently not located, of which there were 9, were given rates.

Table 16.— Frequency Distribution of Cartage Rates Under Proposed Schedule and Schedule as of May 1935

Rate	Number of Producers	
	Proposed Schedule	Schedule in Operation May 1935
.15	2	0
.20	39	5
.23		9
.25	42	4
.28		23
.30	19	10
.33		13
.35		21
.40		14
.44		2
.465		8
Over .465		2
Not located	9	
Haul own	2	2
Total	113	113

As with route organization, the proposed rates and the derived income are suggestions with indications as to the probable results. The rate level may be too high; it may be too low. Experience will indicate the approximate levels at which to establish rates in order to maintain the service under varying economic conditions.

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MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

Bulletin No. 364 June, 1939

The Significance of Body Weight in Breeding for Egg Production

By F. A. Hays

Body weight is one of the recognized measures of value in poultry breeding. This study was an attempt to discover what relationships exist between body weight and production characters, egg size, and mortality, in a flock bred for high fecundity.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE SIGNIFICANCE OF BODY WEIGHT IN BREEDING FOR EGG PRODUCTION

By F. A. Hays, Research Professor of Poultry Husbandry

INTRODUCTION

Body weight in flocks bred for egg production is considered to be important from the standpoint of egg size, persistency, and mortality rate in the laying houses. The opinion is rather prevalent that larger birds within the flock are likely to carry a greater physiological reserve to enable them to carry on more successfully all of the complex functions associated with high egg production.

The literature concerned with the mode of inheritance of body weight has been rather fully reviewed by Maw (1935) and need not be reviewed here. In general, available evidence indicates that body weight in domestic fowl depends upon a series of multiple factors. The inheritance of body weight differences within breeds has not been extensively studied although strain differences are believed to occur.

The relation between body weight and egg weight has been studied by Hadley and Caldwell (1920), Asmundson (1921), Atwood (1923), Jull (1924), Parkhurst (1926), Upp and Thompson (1927), Rhynehart (1929), Hanschildt (1929), and Funk and Kempster (1934). All of these workers report a significant relation between body weight and egg weight. The Blue Book of the Canadian National Poultry Record Association for 1929 reported a significant relation between body weight at the end of the year and mean egg weight in White Leghorns, Barred Plymouth Rocks, White Wyandottes, and Rhode Island Reds. Hays (1930) stated that the largest birds laid the largest eggs up to January first of the first laying year. Knox (1934) found a significant correlation between initial body weight and average egg weight and between average body weight and egg weight for the first laying year. Funk (1935) noted a significant correlation between mean annual body weight and mean annual egg weight in White Plymouth Rocks.

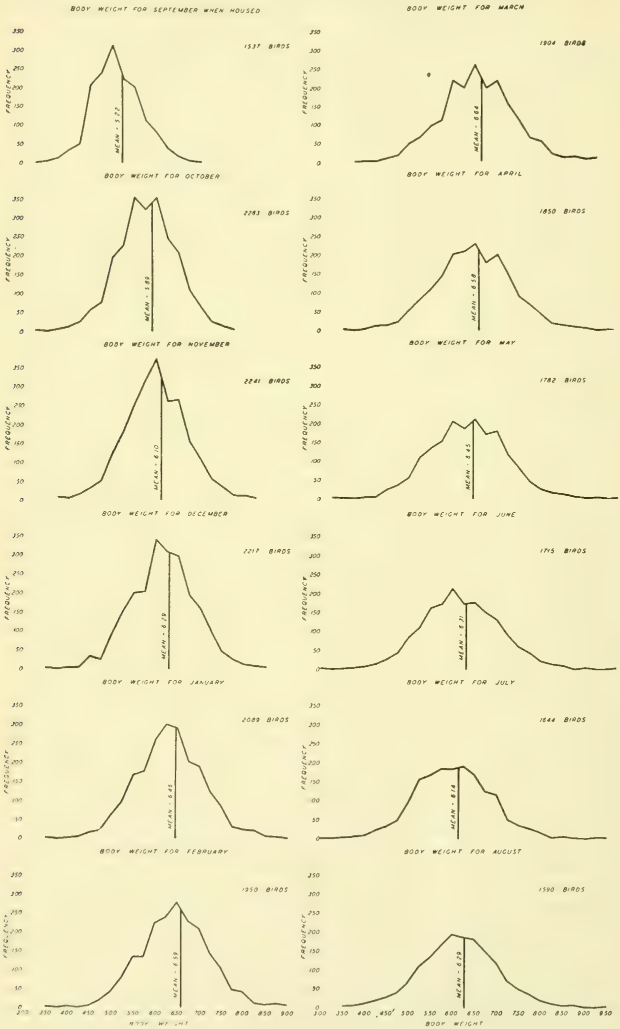
Hays and Sanborn (1933) stated that the most persistent layers were slightly smaller at first egg than were the less persistent layers in Rhode Island Reds. The difference was small, however, and the fact should be kept in mind, as Hays (1933) pointed out, that weight at first egg is directly dependent upon age at first egg in the birds used.

Body weight at the close of the laying year was found to be somewhat greater in the highly persistent birds. Weights taken at the close of the laying year are known to represent the true body weight more nearly than those taken at the beginning of the first laying year when the birds differ widely in age and maturity.

Body weight at sexual maturity was not correlated with laying-house mortality in Hays and Sanborn's (1928) studies. Since the relation between maximum body weight of the first laying year and subsequent mortality has not been studied, there is a possibility that adult size may affect mortality.

The relation between body weight and annual egg production has been considered by a larger number of workers and has been summarized by Jull (1932). The evidence strongly indicates that body weight and total egg production are independent. Knox (1934) reported no correlation between initial or final and average body weight and number of eggs laid. The fact should be noted, however,

CHART 1
FREQUENCY DISTRIBUTION IN BODY WEIGHT DURING THE FIRST LAYING YEAR



that in the various studies body weights were taken at various ages by different investigators.

In most cases there was no uniform measure of body weight such as maximum weight in the first laying year or weight at the end of the first laying year. On the other hand, a summary of Canadian National Egg Laying Contests from 1924 to 1928, reported in their Blue Book for 1931, showed a decided correlation between weight of birds and egg production in Leghorns, Barred Plymouth Rocks, White Wyandottes, and Rhode Island Reds.

Birds Used for Study

The birds used were hatched in 1934, 1935, and 1936. They were all Rhode Island Reds that were used in various breeding experiments. The methods of feeding and management were kept constant. All birds were placed in the laying houses when about 170 days of age. Individual weights were taken on each pullet when housed, and subsequent weighings were made on the same calendar date each month for a full year.

Body Weight During the First Laying Year

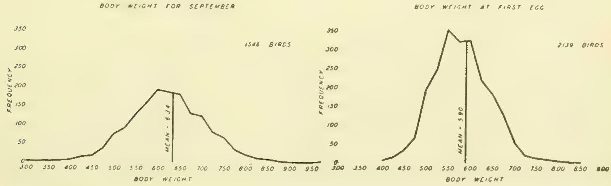
1. *Monthly Body Weight*

The frequency distribution in body weight for all birds weighed at monthly intervals throughout three years and the weight at first egg are recorded graphically in Chart 1. All individual weighings were included to round out the frequency graphs, because the monthly means were not significantly changed when only birds surviving the whole period were included.

A study of the frequency distributions in body weight from September to January indicates skewness in the direction of lighter weight. The graphs further reveal rather compact distributions for body weight during the first half of the laying year. There was some evidence of a bimodal distribution at this time around one mode of about 6 pounds and another mode of about 6.75 pounds. The exact meaning of this apparent bimodal distribution has not been determined.

Beginning with the February weights there was a rather close approach to a normal frequency distribution. This result is suggestive that adult growth is attained at about this time. From April to the close of the first laying year there was an increasing tendency for the curves to flatten out. Such distributions suggest that after mature growth was attained part of the population added weight in the form of fat and another part of the population declined in weight probably because of adverse physiological conditions. This series of graphs illustrates the behavior of a large population in body weight through the first laying year.

CHART 1
FREQUENCY DISTRIBUTION IN BODY WEIGHT DURING THE FIRST LAYING YEAR



The last graph in Chart 1, showing body weight at first egg, has something of a bimodal aspect and indicates that weights taken at this stage of life are not likely to furnish a true criterion of what adult weight may be.

The mean monthly body weight of all birds in all experiments is recorded in Table 1.

TABLE 1. — MEAN MONTHLY BODY WEIGHT

(Three years combined. Includes all birds weighed.)

Month	Number of Birds	Mean Weight (Pounds)
September	1,537	5.20
October	2,283	5.88
November	2,241	6.09
December	2,217	6.27
January	2,089	6.45
February	1,951	6.58
March	1,904	6.63
April	1,850	6.56
May	1,782	6.44
June	1,716	6.30
July	1,644	6.13
August	1,590	6.27
September	1,546	6.32

The mean weight records indicate that the greatest monthly increase occurred during the first month in the laying houses. Only the first two units of about 256 birds each were housed early in September each year, and the third unit of about 250 birds was housed near October 1. On this basis the data showed a mean increase of .68 pound which figure is lower than the actual increase in houses 1 and 2. These data indicate that pullets, if housed when about 10 percent of the birds are actually laying and the others just ready to begin laying, will show a very great increase in weight during the first month. The data show that from October 1 to February 1 there was a monthly increase of nearly .25 pound for each individual.

Maximum body weight of the first laying year was attained about March 1, when the birds ranged between 11 and 12 months of age, after which there was a monthly decline to about September 1 when weight increases were again noted. The data showed a mean weight at housing of 5.20 pounds, a maximum weight of 6.63 pounds, and a final weight of 6.32 pounds. If these are representative of the normal, a weight increase from housing to the maximum would be about 1.5 pounds and a weight loss between the maximum and the final weights would be about one-third pound. The difference between the initial and final weights would be slightly over one pound.

Relation between Body Weight and Egg Weight

2. *Monthly Body Weight and Monthly Egg Weight*

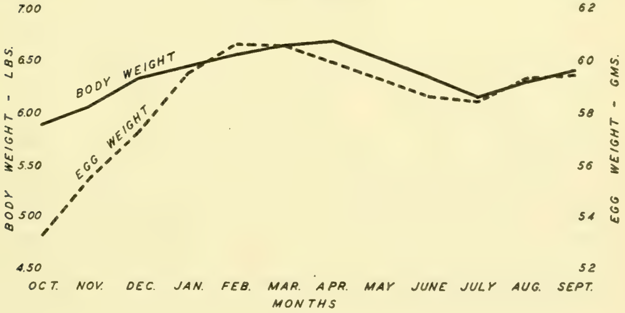
Daily egg weights were taken for a full year on one unit of 250 birds in each of the three years. For studying the relation between body weight and egg weight, only those birds that were bred for egg production and survived the year were included. The gross data are presented in Table 2.

TABLE 2.—MEAN MONTHLY BODY WEIGHT AND EGG WEIGHT

Month	Monthly Body Weight		Monthly Egg Weight	
	Number of Birds	Mean Weight (Pounds)	Number of Birds	Mean Weight (Grams)
October	267	5.89	254	53.2
November	267	6.06	258	55.4
December	267	6.32	249	57.2
January	267	6.43	243	59.4
February	267	6.55	232	60.6
March	267	6.63	241	60.5
April	267	6.68	267	59.9
May	267	6.50	266	59.2
June	267	6.34	264	58.6
July	267	6.14	257	58.4
August	267	6.29	243	59.2
September	267	6.40	217	59.4

The data in Table 2 and Chart 2 show rather remarkable parallelism between mean monthly body weight and mean monthly egg weight up to March 1. Maximum body weight appeared in this group of birds about April 1, and maximum egg weight appeared about February 1 when the birds laid eggs weighing 60.6 grams or 25.7 ounces to the dozen. The summer decline in body weight began with May and a decline in egg weight began with April. Body weight declined until August and egg weight declined until July. These data indicate considerable parallelism between body weight and egg weight throughout the pullet year.

CHART 2
MEAN MONTHLY BODY WEIGHT
AND MEAN MONTHLY EGG WEIGHT
267 BIRDS



3. *Increase or Decrease in Body Weight during the Laying Year, and Winter Egg Weight*

In Table 3, 1309 birds with complete annual records were grouped into three general classes with respect to body weight differences that occurred between the weights taken when the birds were housed at about 170 days of age and the weights taken twelve months later. Individuals that lost more than .25 pound during the year were placed in the first class. Individuals whose weight did not change more than .25 pound during the year were in the second class. Individuals that had a weight increase of more than .25 pound were placed in five subclasses in the third class, depending upon the amount of weight increase.

All eggs laid by these birds up to January 1 were weighed and the mean egg weight for each individual was designated as the winter egg weight. Table 3 is presented to show the relation between body weight increase or decrease in the first laying year and mean winter egg weight.

The group of birds that lost weight during the year and the group that showed no change in weight throughout the year laid small eggs. In the class of birds that showed a weight increase, there was a rather consistent increase in winter egg size with each half pound increase in body weight during the year.

TABLE 3. — WEIGHT INCREASE OR DECREASE FROM HOUSING TO THE END OF THE YEAR, AND WINTER EGG WEIGHT

Class of Birds	Number of Birds	Mean Winter Egg Weight (Ounces per Dozen)
Losing more than .25 lb.	24	22.3
Not changing weight	74	22.5
Gaining		
.26– .74 lb.	251	22.7
.75–1.24 lb.	381	23.0
1.25–1.74 lb.	316	23.4
1.75–2.24 lb.	189	23.4
2.25 lb. or more	74	23.6

Hays (1937) pointed out that, for the flock being studied, the mean winter egg weight must be about 23 ounces to the dozen if the bird is to produce eggs averaging 24 ounces to the dozen for the first laying year. On this basis the data in Table 3 show that a pullet must average to gain not less than one pound in body weight in her first laying year if she is to produce eggs that average 24 ounces to the dozen for the first laying year. Those individuals that had a greater weight increase produced heavier winter eggs. These data point rather strongly to body weight increase as being correlated with egg weight.

4. *Body Weight on March* 1 *and Annual Egg Weight*

Data presented in Table 1 indicate that, with the stock used, maximum body weight of the first laying year appeared when the pullets were between 11 and 12 months of age, or about March 1 when the stock was hatched in eight weekly hatches between March 4 and April 27. Since mature weight is probably dependent largely upon inheritance, it is apparent that body weight taken about March 1 would be the best measure of weight obtainable during the pullet laying year.

Annual egg weight was calculated by determining the mean of all eggs laid by each bird for 365 days, beginning with her first egg. Data on egg weight are available on 486 birds in the various experiments being carried on. These birds were housed in house 1 and represent one of the three units used in the weight studies.

From a tabulation of body weight on March 1 against mean annual egg weight, the following constants were derived:

Number of birds	486
Mean body weight, pounds	6.72
Weight standard deviation	±.80
Mean annual egg weight, grams	58.59 (24.8 oz. per dozen)
Egg weight standard deviation	±4.05
Coefficient of correlation	+.3990 ± .0257
Correlation ratio	.4661

The variability in body weight was not excessive, since it amounted to only 11 percent of the mean. The birds used may therefore be said to be reasonably uniform in mature body weight.

Egg weight for the year was 58.59 grams or 24.8 ounces to the dozen. Variability in egg weight was less than 7 percent, which indicates a high degree of uniformity.

Regression of egg weight on body weight was shown not to be strictly linear by Blakeman's test. The coefficient of correlation between egg weight and body weight was .3990 ± .0257, and the correlation ratio was .4661. The magnitude of these constants indicates that egg weight depends in considerable measure upon body weight. Almost 22 percent of the variation in egg weight may be attributed to variation in body weight.

Relation between Body Weight and Persistency

5. *Body Weight at Housing, and Persistency*

The question arises as to whether pullets that are heavy in weight when housed are likely to show greater persistency in laying than birds that are lighter in weight when housed. The coefficient of correlation between weight at housing and annual persistency will furnish some information. The following constants were calculated:

Number of birds	1513
Mean weight at housing, pounds	5.16
Housing weight standard deviation	±.60
Mean annual persistency, days	334.46
Persistency standard deviation	±40.92
Coefficient of correlation	+.1771 ± .0168
Correlation ratio	.2454

The birds averaged to weigh 5.16 pounds when housed and there was a range in weight from 3.25 to 7.24 pounds. The coefficient of variation was almost 12 percent. Since this population includes birds from all experiments, there would be a somewhat greater range in weight than would appear in birds bred for high egg production.

The mean persistency within the laying year was 334.46 days, with a range from 82 to 366 days. The coefficient of variation in persistency was over 12 percent. It is evident that this somewhat mixed population was highly variable in persistency.

The coefficient of correlation between weight at housing and annual persistency was .1771 ± .0168 but regression was not linear. The correlation ratio was .2454 and indicates that about 6 percent of the variation in persistency was associated with variation in weight at housing. This is not an intimate association so that weight at housing cannot be considered an important criterion of persistency in laying.

6. *Body Weight on March* 1 *and Persistency*

Poultrymen generally attach much importance to the weight of birds at the close of the winter laying season. In this connection it is desirable to know whether large birds are likely to be more persistent. The coefficient of correlation between body weight on March 1 and annual persistency will supply some information on this point.

Number of birds	1338
Mean weight March 1, pounds	6.62
Weight standard deviation	±.75
Mean annual persistency, days	334.01
Persistency standard deviation	±41.56
Coefficient of correlation	−.0905±.0183
Correlation ratio	.1655

Range in body weight was wide, extending from 4 to 9.5 pounds. The coefficient of variation in weight was somewhat above 11 percent. A mean of 6.62 pounds indicates that the birds were large at maturity.

Mean persistency was 334 days and the range was from 82 to 366 days. The value of the mean indicates that the majority of the birds were highly persistent layers.

The coefficient of correlation is of negative order and is statistically significant. The regression of persistency on weight was found to be nonlinear so that the correlation ratio, .1655, may be used to measure association. The magnitude of this constant is sufficient to indicate a slight negative relation between adult weight and persistency of laying. These data are suggestive that heavier birds at maturity may not be as persistent as birds of somewhat lighter weight.

Relation between Body Weight and Mortality

7. *Body Weight at Housing, and Mortality*

Since the pullets were all housed at about 170 days of age, the relation between body weight at housing and subsequent mortality may be considered. In Table 4 the birds are grouped into classes with respect to weight at housing, and mortality in each weight class is recorded for a 365-day period. The data cover the flocks hatched in 1934, 1935, and 1936 in all experiments, and indicate that pullets that weighed less than 4.25 pounds when placed in the laying houses had a significantly higher mortality rate (32.46 percent) than birds having greater weight when housed (25.87 percent).

Mean mortality rates for the different weight classes were fitted to a straight line, omitting four birds weighing less than 3.5 pounds and eight birds weighing more than 6.75 pounds. These data showed an essentially normal frequency distribution with respect to weight. The standard error of estimate was calculated for mortality rate, and a range covering twice the value of the standard error of estimate was found to include all mortality means. The regression of mortality rate on weight at housing was strictly linear, and mortality rate in the laying houses may be expected to decrease from about 30 percent for the smaller birds to about 22 percent for the larger birds. This is not an intimate relation between weight at housing and subsequent mortality, yet it is significant.

Table 4.—Weight when Housed and Subsequent Mortality

Weight Class Pounds	Total Birds	Percent Mortality
3.00–3.24	1	0.00
3.25–3.49	3	66.67
3.50–3.74	18	27.78
3.75–3.99	44	29.55
4.00–4.24	91	34.07
Total or mean	157	32.46
4.25–4.49	122	25.41
4.50–4.74	308	30.19
4.75–4.99	292	28.08
5.00–5.24	399	26.32
5.25–5.49	267	25.47
5.50–5.74	245	23.27
5.75–5.99	137	19.71
6.00–6.24	97	23.71
6.25–6.49	46	23.91
6.50–6.74	20	25.00
6.75–6.99	5	0.00
7.00–7.24	3	0.00
Total or mean	1,941	25.87
Grand Total or Mean	2,098	26.36

8. *Increase or Decrease in Body Weight between Housing and March* 1, *and Subsequent Mortality*

Pullets, when housed at the time they are ready to lay, usually show a marked increase in body weight after housing, as has already been shown. It is desirable to know whether weight increases or decreases between housing and maximum weight about March 1 show a significant relation to subsequent mortality. Data are available on 1933 birds which have been classified into three classes: Those losing weight; those showing no weight change; and those showing a weight increase. In Table 5 the results by years are recorded, together with the mean of the three years.

The highest mortality occurred in the birds that lost weight from the time of housing up to March 1 and in the birds that failed to show an increase in weight. In the class that gained weight, there was a consistent decline in mortality as the amount of gain in weight increased up to about 1.5 pounds. These data show that birds having a mean weight increase of about 1.5 pounds between September and March were less likely to die later than were birds that failed to make such a weight increase. As a basis for culling about March 1 to reduce mortality, there would have been an advantage in this flock in removing individuals that weighed less than 6.25 pounds.

TABLE 5.—WEIGHT INCREASE OR DECREASE FROM HOUSING TO MARCH 1, AND SUBSEQUENT MORTALITY

Classes of Birds	1934		1935		1936		Three Years	
	Number of Birds	Mortality Percent	Number of Birds	Mortality Percent	Number of Birds	Mortality Percent	Total Birds	Mean Mortality Percent
Losing more than .25 lb.	3	100.00	2	50.00	3	0	8	50.00
Not changing weight	17	64.71	3	0	11	9.09	31	24.60
Gaining								
.26– .74 lb.	77	54.55	33	6.06	75	13.33	185	24.65
.75–1.24 lb.	175	39.43	119	10.08	171	11.70	465	20.40
1.25–1.74 lb.	225	33.78	193	8.81	182	8.79	600	17.13
1.75–2.24 lb.	136	31.62	158	12.03	127	10.24	421	17.96
2.25 lb. or more	51	21.57	100	16.00	72	9.72	223	15.76
Total Birds	684		608		641		1,933*	

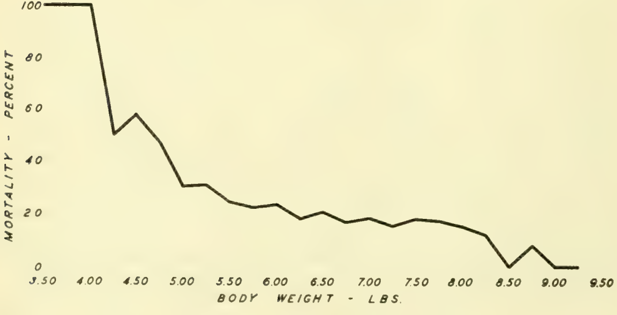
*This table includes 3 fewer birds than Chart 3 because 3 individuals were not weighed when housed but were weighed for the remainder of the year.

9. *Body Weight on March* 1 *and Subsequent Mortality*

The fact has been pointed out in Section 1 that maximum body weight of the first laying year was attained about March 1 and that weights taken at this time probably are the best measure obtainable of the body weight of a flock. It is highly desirable to know whether this mature body weight is in any way related to subsequent mortality.

A population of 1,936 pullets was classified into quarter-pound weight classes starting with the minimum of 3.5 pounds and extending to a maximum of 9.5 pounds with respect to weight on March 1. The subsequent mortality was calculated to the end of a 365-day period in the laying houses for each weight class. The data are presented in Chart 3.

CHART 3
BODY WEIGHT ON MARCH FIRST
AND SUBSEQUENT MORTALITY
1936 BIRDS



There were 29 birds that weighed less than 5 pounds on March 1. These birds were probably pathological when weighed, and their mortality ranged from

40 to 100 percent. Beginning with the class of birds weighing 5 pounds, there was a consistent decline in mortality as weight increased. Mortality was about 30 percent for the group weighing from 5 to 5.24 pounds and fell well below 10 percent when weight was greater than 8.5 pounds. In this particular group of birds it was necessary to have a mean weight of 7.5 pounds or more if subsequent mortality was to be less than 15 percent. In other words, culling of small birds at twelve months of age would appear to be an effective means of reducing summer mortality.

Relation between Body Weight and Egg Production

10. *Body Weight on March* 1, *and Annual Egg Production*

Mature body weight of the first laying year, taken about March 1, is probably one of the best gross measures of adult size. Weight records and annual production records are available on 1,338 birds from which the correlation between body weight and annual egg production was determined. The following constants were obtained:

Number of birds	1338
Mean body weight, pounds	6.62
Weight standard deviation	±.75
Mean annual production	213.48
Production standard deviation	±42.20
Coefficient of correlation	−.1526±.0180
Correlation ratio	.1901

The data show that the birds were of a large strain and that the variation in weight was not excessive. Annual egg production was high, with a rather wide range of variability.

The coefficient of correlation was of a negative order, but regression was not strictly linear so that the correlation ratio of .1901 measures the true association. There was a statistically significant negative correlation between body weight and annual egg production. The squared value of the constant, however, showed that less than 4 percent of the variation in annual egg production was associated with variation in body weight. In this flock body weight was but remotely associated with egg production.

11. *Increase or Decrease in Body Weight during the Laying Year, and Annual Egg Production*

A total of 1,309 birds with complete annual weight and production records was again classified into three classes with respect to weight increase or decrease from time of housing to the end of twelve months in the laying houses, and the mean annual egg record of each class recorded.

Table 6 shows that the group of birds gaining one-half pound during a year in the laying houses laid a slightly greater number of eggs than any other group. The eggs laid by this group of birds fell below a 24-ounce standard for the year. On the basis of volume of egg material produced, the group gaining 1.5 pounds was equal to the group gaining .5 pound, and egg size for the former was satisfactory throughout the year. From the standpoint of number of eggs and size of eggs, an increase in body weight of about 1.5 pounds during the first laying year would seem to be desirable in this flock.

TABLE 6. — WEIGHT INCREASE AND DECREASE, AND ANNUAL PRODUCTION

Class of Birds	Number of Birds	Annual Production (Eggs)
Losing more than .25 lb.	24	197.7
Not changing weight	74	212.1
Gaining		
.26– .74 lb.	251	221.4
.75–1.24 lb.	381	217.0
1.25–1.74 lb.	316	214.1
1.75–2.24 lb.	189	210.1
2.25 lb. or more	74	201.3

12. *Monthly Body Weight and Monthly Egg Production*

In this study only birds in the high fecundity experiment and birds with complete annual records were used. A total of 786 birds out of 1,309 with complete records came from the experiments on high fecundity. The hatching dates of these birds covered a 49-day range between March 3 and April 26. Housing facilities were available for 750 pullets each year in three units. The first unit was made up of hatches 1 and 2 and a part of hatch 3, housed near September 1. The second unit included the rest of hatch 3 and practically all birds from hatches 4 and 5, housed about September 15. The third unit was made up from hatches 6, 7, and 8, housed about September 28. All body weights were taken throughout the year on the same monthly calendar date that the birds were housed. Mean monthly weights for the different houses were combined to give a mean for the total population each month. Both weight records and egg production records cover thirteen months.

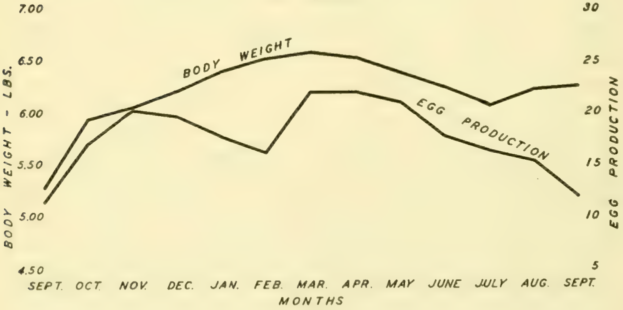


CHART 4
MEAN MONTHLY BODY WEIGHT
AND MEAN MONTHLY EGG PRODUCTION
786 BIRDS

The graph for body weight (Chart 4) indicates a very rapid increase during the first two months in the laying houses. During this period egg production ran parallel with body weight. From November to March, the increase in body weight was regular but less rapid. In December, January, and February, winter pause appeared and greatly reduced egg production. Mature body weight was attained in March (6.57 pounds) and was accompanied by maximum egg production. From April to August, body weight fell to 6.21 pounds, representing a loss of about .4 pound. During this same period egg production declined at a slightly greater rate than body weight. In the month of September, body weight increased slightly to 6.24 pounds, but egg production fell to about the same level as appeared in the first laying months. These data in general showed considerable parallelism between body weight and monthly egg production during the first laying year. Since the mean hatching date was about March 25, the mean age on March 15 was about 355 days when mature body weight was attained.

Summary

Body weight records were obtained on 2,283 Rhode Island Red pullets to study the significance of body weight in breeding for egg production. The data obtained seem to warrant the following deductions:

1. Laying pullets increased in weight at the highest rate during the first month of laying. After the first month there was a monthly increase of about one-fourth pound up to the mature weight attained at eleven to twelve months. During summer there was a decrease in body weight up to September, averaging about one-third pound for each individual.

2. There was considerable parallelism between mean monthly body weight and mean monthly egg weight. Maximum egg weight occurred about one month earlier than maximum body weight.

3. Satisfactory winter egg weight did not occur unless pullets averaged to gain one pound or more in weight from housing to the end of the laying year. Increases greater than one pound were accompanied by larger winter eggs.

4. There was a significant positive correlation between maximum body weight and annual egg weight.

5. A statistically significant, though not intimate, correlation was observed between weight at housing and persistency.

6. Maximum body weight gave a statistically significant negative correlation with persistency, but the constant was of small magnitude.

7. There was a consistent decline in mortality in the laying houses as the weight of pullets at housing increased.

8. Groups of pullets having an increase in weight of 1.5 pounds between housing and March 1 had the lowest subsequent mortality. Removal of light-weight pullets on March 1, therefore, offers an effective means of reducing subsequent mortality.

9. Mature body weight showed a statistically significant negative correlation with annual egg production. The absolute magnitude was so small, however, as to indicate only a remote association.

10. Pullets increasing one pound in weight during the first laying year gave the most satisfactory egg records. Birds losing weight or with unchanged weight gave unsatisfactory egg records.

11. Considerable parallelism was observed between monthly body weight and monthly egg production. The highest level of egg production occurred when body weight was at its maximum in March and April.

12. In general, body weight offers a valuable guide to the breeder, particularly from the standpoint of egg size and laying-house mortality.

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MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

Bulletin No. 365 July 1939

Product-Costs of Milk to Dealers in the Springfield Area, 1935

By Alfred A. Brown and J. Elizabeth Donley

Unstable markets tend to hinder the milk industry in its efforts to serve the public. The unsettled conditions are due chiefly to the differences in dealers' product-costs. The variations in product-costs to dealers in the Springfield Market Area have been analyzed and suggestions made for reducing them.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

PRODUCT-COSTS OF MILK TO DEALERS IN THE SPRINGFIELD AREA,

1935*

By Alfred A. Brown, Assistant Research Professor, and J. Elizabeth Donley,
Research Assistant, in Agricultural Economics and Farm Management

The average price of milk delivered to plants in the Springfield market area in 1935 was $2.82 per hundredweight or slightly more than 6 cents per quart of 3.7 percent milk. Analysis of the structure on which this simple price was fabricated reveals a number of relationships of probable interest to both producers and distributors. Among these items are the variations in product-costs[1] to individual dealers; the cause of the variations; the extent and persistence of the variations; the action which producers or distributors may initiate to take advantage of the variations.

In the process of marketing a commodity for which the demand is relatively inelastic, marked variations in prices received by the sellers would be smoothed out by adjustments in the supply. The characteristics of the commodity, the degree and persistence of the variation, the astuteness of the seller, and his freedom to act in accordance with the dictates of economic considerations would influence the speed and completeness with which such adjustments might be made. Since wide differences have been common in the product-costs to dealers (producers' f. o. b. selling prices) in many milk markets, it would appear that dairymen as sellers are unable to effect adjustments because of (1) certain rigidities in the market; (2) ignorance of the existence of such differences; (3) inability as individuals to accomplish the desired results, plus the absence of necessary leadership to effect the organization essential for such an achievement; (4) fear that the probable cost of bringing down the price structure would more than offset the gains to be made by the responsible group; (5) a personal fatalistic indifference; (6) a personal sense of responsibility toward improving conditions through arbitration rather than by other means; and (7) certain rigidities in production.

Significance of Average Price

The average buying price for the market is significant as an indicator of the level of prices. Out of this "level" arise the buying prices of the various dealers, and out of their prices those which the farmers thought they should receive. The maze through which the average price moves towards the individual producer is schematically presented in figure 1.

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*This report is part of a general study of milk marketing in the Springfield Milkshed. Acknowledgement is made of the helpful assistance given by dairymen, distributors, local health offices, the Massachusetts Milk Control Board, and the Milk Administration of the State of Connecticut.

[1] The weighted average cost to the dealers per hundredweight of milk purchased from producers. This seems to be the most suitable measure for comparing the hundredweight values of the purchases by dealers in a market. It is computed by dividing the given amount of money due producers f. o. b. the market by the total pounds purchased from them.

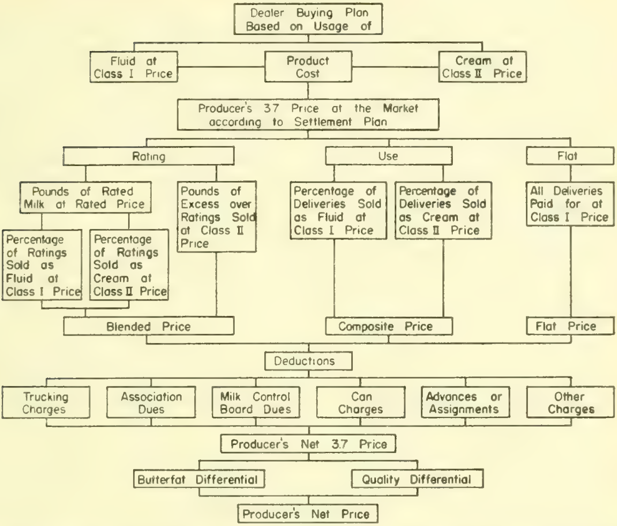
Dealer Buying Plan Based on Usage of
Fluid at Class I Price
Product Cost
Cream at Class II Price
Producer's 37 Price at the Market according to Settlement Plan
Rating
Use
Flat
Pounds of Rated Milk at Rated Price
Pounds of Excess over Ratings Sold at Class II Price
Percentage of Deliveries Sold as Fluid at Class I Price
Percentage of Deliveries Sold as Cream at Class II Price
All Deliveries Paid for at Class I Price
Percentage of Ratings Sold as Fluid at Class I Price
Percentage of Ratings Sold as Cream at Class II Price
Blended Price
Composite Price
Flat Price
Deductions
Trucking Charges
Association Dues
Milk Control Board Dues
Can Charges
Advances or Assignments
Other Charges
Producer's Net 3.7 Price
Butterfat Differential
Quality Differential
Producer's Net Price

Figure 1. Schematic Diagram Showing Methods by Which Producers' Prices are Determined.

The weighted average price or the price level is of additional significance since it is subjected to the manipulation of price-determining agencies. From 1917 to 1934 the New England Milk Producers' Association negotiated price contracts with distributors. Since 1934 the Massachusetts Milk Control Board has regulated the level of buying prices which should prevail in secondary markets in Massachusetts.

The control of both agencies over the price level has been incomplete. Inability to negotiate contracts with all dealers in a market limited somewhat the effectiveness of the Association's influence, the extent of the limitation varying with market conditions. The Milk Control Board overcame this difficulty but has been handicapped by one fully as significant. As yet it regulates only the price paid for milk produced in Massachusetts and used for fluid purposes. The Board does standardize the method of determination and calculates the price to be paid for milk in excess of Class I sales, but the level of this price is determined by market conditions. The Board has but little influence over prices to be paid for milk not produced in Massachusetts and not subject to Federal orders.

The 1935 Price Level

The monthly average product-cost ranged from $2.58 per hundredweight (5.5 cents per quart) in June to $2.99 per hundredweight (6.5 cents per quart) in November. The monthly product-costs are given in table 1 and the movement is illustrated by figure 2.

The upward change in the price level which came in March was caused chiefly by an increase of 46.5 cents per hundredweight in the price of Class I milk, effective March 10, 1935. The level continued upwards in April despite a slight reduction in the proportion of milk sold as fluid. During that month, the advance in the Class I price was effective for two full pay periods, and in addition the Class II price advanced slightly.

With the exception of the upward movement which took place in the early spring, the variation in the price level followed a somewhat typical course.

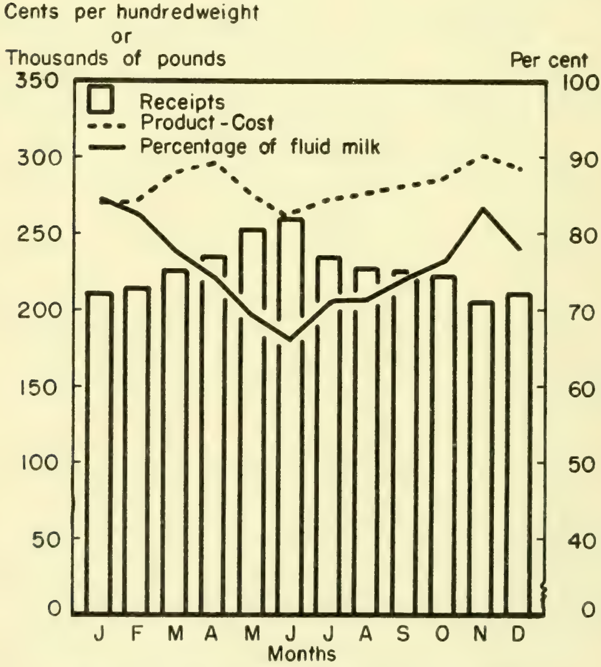

Figure 2. The Monthly Average Product-Cost of Market Receipts Springfield Market Area—1935

TABLE 1.—AVERAGE PRODUCT-COST, AVERAGE DAILY PURCHASES, AND PERCENTAGE OF FLUID MILK RECEIVED IN THE SPRINGFIELD MARKET AREA, 1935

Month	Product-Cost (Dollars per Hundredweight)	Average Daily Receipts (Pounds)	Fluid Milk (Percent)
January	2.703	210,482	84.6
February	2.714	214,417	82.7
March	2.893	226,124	77.4
April	2.966	235,879	74.3
May	2.749	253,538	69.0
June	2.587	260,455	66.1
July	2.735	235,863	70.8
August	2.757	232,013	71.2
September	2.812	224,314	74.1
October	2.858	223,625	76.4
November	2.996	205,579	83.4
December	2.931	211,645	78.1
Average	2.825	227,897	75.3

Product-Costs to Dealers

The 1935 average product-cost to dealers buying on some basis other than a flat plan varied from $2.31 per hundredweight (4.9 cents per quart) to $3.04 per hundredweight (6.53 cents per quart) — a range of 73 cents per hundredweight (1.5 cents per quart). (Table 2.) The range in monthly cost of purchases among the dealers was lowest in February, when it was 58 cents per hundred pounds, and highest in June at $1.15 per hundred pounds. The monthly data are shown in table 3.

TABLE 2.—PRODUCT-COST OF 16 USE-PLAN DEALERS

Average, 1935

Dealer	Dollars per Hundredweight	Dealer	Dollars per Hundredweight
A	3.04	I	2.71
B	3.03	J	2.71
C	2.99	K	2.67
D	2.93	L	2.67
E	2.79	M	2.64
F	2.78	N	2.57
G	2.78	O	2.56
H	2.73	P	2.31

TABLE 3.—MONTHLY RANGE IN DEALERS' PRODUCT-COSTS, 1935*

(Dollars)

Month	Maximum	Minimum	Range
January	2.84	2.25	.59
February	2.85	2.27	.58
March	3.18	2.34	.84
April	3.14	2.40	.74
May	3.02	2.19	.83
June	2.92	1.77	1.15
July	3.09	2.31	.78
August	3.11	2.32	.79
September	3.07	2.40	.67
October	3.15	2.44	.71
November	3.21	2.47	.74
December	3.17	2.42	.75
Average	3.04	2.31	.73

*Exclusive of Flat Plan.

The standard deviation of dealers' product-costs from the average market cost was ±17.2 cents for 1935. In other words, approximately two-thirds of the dealers had costs within 17.2 cents of the market average. The limit within which the bulk of the dealers' product-costs came was smallest in February (±14.7 cents) and largest in June (±29.8 cents).

Important relationships between the percentage of total deliveries going into Class II usage and the variation in dealers product-costs in 1935 are brought out by reference to figure 3.

The normal expansion from February through June in the percentage of milk disposed of as Class II was accompanied by a normal increase in the spread of dealers' product-costs around the market average. The slight drop in Class II usage from June to July was associated with a very pronounced contraction in the range of prices. The continued decline in Class II disposal from July through November was associated with an increase in the spread of dealers' product-costs rather than with the expected decrease.

The direction of the June–July movement would be regarded as normal. The severity of the drop in the spread, however, warrants detailed explanation.

A narrowing of the spread in product-costs may be caused by a number of forces acting independently or together. There may be a relatively uniform reduction in the proportion of milk disposed of as Class II by all dealers. There may be a sharp decline in the Class II disposal of those dealers carrying the larger proportions of it. There may be a marked increase in the proportion of Class II disposal by those dealers handling relatively little. There may be a reduction in the Class I–Class II price ratio. All of these forces were operating during the June–July period 1935.

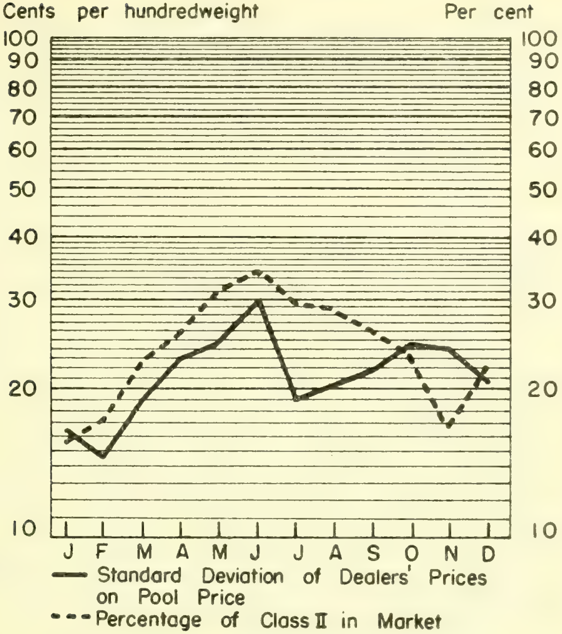

Figure 3. The Relationship Between the Percentage of Class II Milk in the Market and the Variation of Dealers' Product-Costs from the Market Average Monthly—1935

Eleven of the principal Use-Plan dealers had reductions in their Class II disposal; one had only a very slight change upward; and one had a very substantial increase. Two dealers who disposed of 44 and 50 percent of their June deliveries as Class II had reductions of 29 and 35 percent respectively in July. The distributor whose disposal of deliveries in Class II was relatively low had an increase of 45 percent in July as compared to June. The Class I–Class II price ratio declined from 3.14 in June to 2.76 in July.

The joint operation of these forces was responsible for the marked reduction from June to July in the spread in dealers' product-costs.

The inverse relationships which existed during the last half of 1935 between the percentage of Class II milk in the market and the variation in dealers' product-costs — unsound as they may appear — were and probably are normal for this market, with the exception of the extreme changes from June to July in the spread of dealers' product-costs. Biological forces, management practices —

both dealer and producer—, and market characteristics account for the increased variation in product-costs as the percentage of milk disposed of as Class II declined.

Cows naturally tend to dry up during the summer months. There was and probably is greater variation among herds in this tendency than in the tendency to increase in production which occurs in the spring months. Feeding practices expressed in terms of supplementary barn feeding, condition of pasture, and pasture management would influence the rate and location of reductions in production. The extent to which available practices would be used and adverse conditions overcome depends not only upon the current but also upon the fall and winter market for milk.

Market characteristics, such as the volume of trade which leaves the area during the vacation period and the distribution of that reduction in Class I sales among the dealers, would affect the variation in dealers' product-costs. The temporary reduction in Class I sales was not uniform and resulted in an irregular pattern. Several distributors who had practically no change in fluid sales had reductions in deliveries which brought their ratio of purchases to sales closely in line. This favorable adjustment in some instances made product-costs approximate the price paid for milk in Class I usage. Since a few of the dealers were still disposing of a substantial proportion of their receipts as Class II, the size of the variation increased.

Limited though the observations are to one year, it is reasonable to conclude that under present methods of calculating dealers' product-costs, seasonal increases in the percentage of Class II milk in the market cause increases in the spread in product-costs, the size of the spread depending mostly on the Class I–Class II price ratio. Conclusions pertaining to the seasonal decreases in the percentage of milk in Class II usage and changes in the spread in dealers' product-costs are less surely formed. That inverse relationships may exist during this period is not questioned. It would be sheer coincidence, however, if the situation that existed during the latter half of 1935 were characteristic throughout.

Month-to-Month Variation in Individual Dealer's Product-Costs

Product-costs to sixteen dealers in the market were analyzed in order to determine the extent, the characteristics, and so far as possible the causes of variation. These dealers accounted for their purchases of milk from producers on some basis other than a flat plan. They handled 85.6 percent of all purchases in the market. Their records were sufficiently accurate and detailed so that a thorough analysis could be made.

Study of the product-costs indicated that there were apparently four cost groups in the market, and the data were accordingly subdivided for further consideration. For convenience, the groups were numbered in descending order from high to low cost, I, II, III, and IV, and will hereafter be referred to by number.

The minimum seasonal variation in the product-cost to any one dealer was 30 cents per hundredweight; the maximum, 75 cents. The full significance of the monthly variation in the product-cost of a particular dealer depends on the actual cost as well as the range. The dealer who had the minimum range in his monthly product-cost was fifth in a group of sixteen arranged in descending order for consistency of having high cost of supplies. In the same array the dealer with the maximum range in monthly product-cost was thirteenth.

Dealers tended to hold the same relative positions with respect to product-cost throughout the year. Consistent high costs were just as characteristic as persistent low ones, although the extremes were more pronounced.

The schematic diagram, figure 4, gives the monthly rank of each distributor according to the group in which his product-cost placed him.

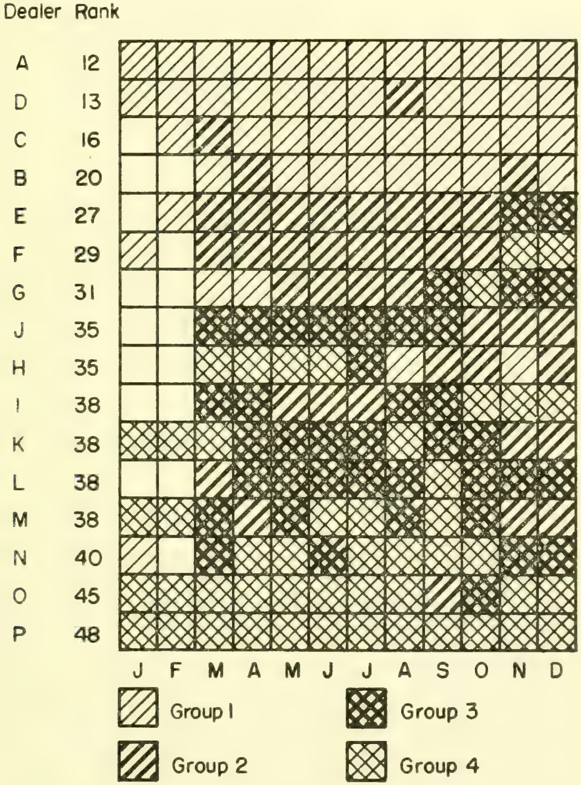

Figure 4. Sixteen Use-Plan Dealers Ranked According to Consistency of Position in an Array of Product-Costs
Monthly—1935

Associated with the relative position of the distributors in the array is the range in product-costs among those in each of the four groups. Except for one of the extremes it tended to be small and fairly uniform; 11, 8, 7, and 8 cents respectively. In other words, there was not a marked variation in the product-costs of dealers within each group.

The total range in costs is not, however, the sum of the group differences. To them must be added the spread between the minimum and maximum costs of adjacent groups, which for groups I and II was 14 cents. Between groups II and III there was an overlapping of these costs of 2 cents and between groups III and IV there was a spread of 3 cents.

So far as cost of milk supply is concerned, one group of dealers can be set apart as high product-cost operators. There was a relatively wide gap between this group and the bulk of the dealers, whose product-costs decreased by neither equal nor wide margins.

Purchases of the Four Groups

The sixteen Use-Plan[2] dealers whose product-costs were arranged by groups handled 85.6 percent of all purchases in the market. Group I, with the highest product-costs, handled 31.5 percent of the quantity purchased by the sixteen dealers; groups II and III handled 19.4 and 21.1 percent respectively; and group IV, 27.8 percent. Within each group, a single dealer was outstanding because of the large volume of purchases which he handled compared to the other dealers in his group. The proportion of the group purchases handled by the principal dealer in group I was 72.9 percent; in group II, 72.6 percent; in group III, 64.4 percent; and in group IV, 47.2 percent.

A certain amount of orderliness seems evident in an industry heretofore commonly represented as disorderly. The orderliness, however, is one of organization, hierarchical in form.

Causes of Variation in Dealers' Costs F. O. B. the Market

Since the relationship between producer and distributor in 1935 was essentially on an agency basis, the only legitimate cause for variations in dealer's product-cost was a variation in the amount of Class II milk handled. Under a system which provided that distributors should use the established hundredweight prices for Class I and Class II milk, the distributor's product-costs in a given pay period would vary inversely with the percentages of Class II handled. Annual average product-costs would vary among dealers, not only in relation to their proportion of Class II but also in accordance with the pay period distribution of the Class II milk throughout the year.

The effect of variations among the dealers in the proportion of Class II milk handled on their product-costs increased and diminished directly with changes in the ratio of Class I and Class II prices. The closeness of the relationship is shown graphically in figure 5. Within the limits of reasonable prices for Class I and Class II milk, smaller differences are created in the product-cost when the ratio is low than when it is high. For example, in January when the Class I price was one and seven-tenths of the Class II price, a 1.1-cent variation existed in the product-costs for each point difference in the percentage of milk in Class II. In June when the Class I price was three and one-tenths of the Class II price, each point variation in Class II caused a difference of 2.35 cents in the dealers' product-cost.

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[2] Dealers who calculated product-cost on the "use" basis; i. e., includes so-called rating plan dealers.

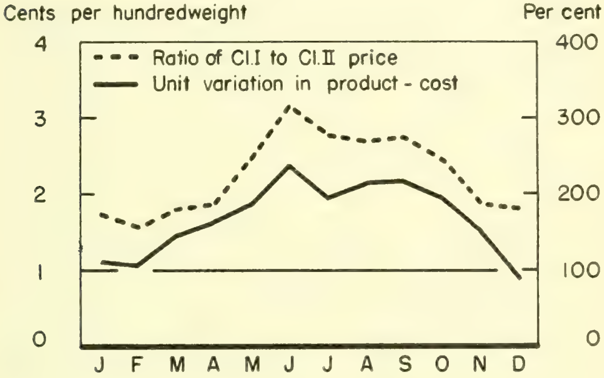

Figure 5. The Relationship Between the Class I—Class II Price-Ratio and the Unit Variation in Product-Cost Associated with Each Point Change in the Percentage of Class II Milk Handled Monthly—1935

Cause of Variation in Percentage of Class II Handled by Dealers

It is very significant that over a period of some duration, marked differences could continue in the proportions of Class II milk handled by the various dealers in the Springfield–Holyoke–Chicopee market area. The obviousness of the significance should be apparent, since it was these differences that accounted for the variation in the dealers' product-costs. It would appear for the most part that so long as all dealers had to use identical class prices they were not greatly concerned about the level at which their individual product-cost happened to settle. One might also expect that even though distributors were not sensitive to the situation their producers would initiate action which would tend to remove existing disadvantages. No such result has occurred, however, in this milkshed.

The basic cause of variation in handlings of Class II milk by the dealers is the type of management, which expresses itself in business practice and business philosophy.

Distributors may control their proportion of Class II milk in a number of ways. They may select producers who manage their herds so as to achieve stable production. They may expand or contract their payroll; i. e., the number of producers from whom they purchase milk. They may, during periods of flush production, require producers to retain a specified proportion of the day's output. They may, if the existing policy is to buy closely to fluid requirements, rely on other dealers for reserves.

Data have not been gathered which would indicate the extent to which dealers make use of these last two practices. Of the other techniques, selection of producers on the basis of relatively even production is the more important. Distributors handling a low percentage of Class II milk had a small turnover of producers, the average for the group being 8.1 percent. Dealers whose proportion of Class II milk was high had a relatively large turnover of 23.9 percent among their producers. (Table 4.) Except that their Class II handlings might have been greater, adjustment of payroll as measured by producer-turnover is not intensively used as a means of bringing purchases and sales into line.

TABLE 4.—RATE OF PRODUCER ADJUSTMENT BY DEALERS IN GROUP I AND GROUP IV.

Dealer	Number of Producers		Ratio of Part-time to Total Producers
	Total	Part-time	
Group I			
A	39	5	13.8
B	15	3	20.0
C	26	5	19.2
D	189	9	4.7
Totals	269	22	
Average			8.1
Group IV			
M	39	3	7.6
N	198	72	36.3
O	62	5	8.0
P	182	35	19.2
Totals	481	115	
Average			23.9

Dealers who have high product-costs (on the basis of their deliveries per day per dairy) select producers who manage their herds so as to have relatively even production. Using the production records of full-time[3] producers for the months of February, May, August, and November as being typical of the year, the range in production was 41.5 pounds for those dairymen selling to dealers in group I and 59.1 pounds for those selling to dealers in group IV. The range in production, however, was but 18.5 percent of the mean for group I as contrasted with 38.0 percent for group IV. The deliveries per day per dairy and the index of delivery per day per dairy for the selected months are given in table 5.

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[3] Similar results secured when records of all producers were used.

TABLE 5.—DELIVERIES PER DAY PER DAIRY TO DEALERS IN GROUP I AND GROUP IV.

Selected Months, 1935

Month	Deliveries to Group I Dealers		Deliveries to Group IV Dealers	
	Actual (Pounds)	Index*	Actual (Pounds)	Index*
February	215.5	96.3	145.1	93.5
May	243.3	108.7	185.9	119.8
August	232.1	103.7	160.1	103.2
November	201.9	90.2	126.8	81.7
Range	41.5	18.5	59.1	38.1

*Average daily deliveries in 1935=100

The product requirements which the two groups of dealers expected their producers to satisfy differed substantially with respect to size of average daily deliveries and butterfat test. Average deliveries per day per dairy were 223 pounds for group I compared to 155 pounds for group IV. The maximum was 243 pounds in May and the minimum 202 pounds in November for the high-cost group, contrasted with 186 and 127 pounds for the same months for the low-cost group. The spread varied from 58 to 75 pounds or from two-thirds to nearly a full 40-quart jug.

The distribution of producers among dealers of the two groups also indicates that volume of production was a factor to be considered. Out of a total of 267 full-time producers selling dealers in group IV, 75 percent produced on the average more than two 20-quart jugs daily; 50 percent produced more than three 20-quart jugs daily; but only 13 percent produced more than six 20-quart jugs daily. Among the 224 producers selling the dealers in group I, 88 percent on the average produced more than two 20-quart jugs daily; 75 percent produced more than three daily; and 33 percent produced more than six daily. The data are given in table 6.

The average butterfat test of purchases ranged from 3.88 to 4.02 percent for dealers in group I, and from 3.71 to 4.07 percent for dealers in group IV. (Table 7.) Differences in the requirements of the two dealer groups are not too evident in the comparison of the average butterfat content of their purchases. There is, however, a slight difference in favor of group I.

The high proportion of producers with a small volume of business who sell the low-cost group may be accounted for by a number of factors other than direct selection. It is possible that many of the so-called small producers were just getting into the dairy business in 1935 and, not having been available in the selective takings of the high-cost group, gravitated to their only alternative. This process is the opposite of positive; it is, in fact, apt to be very passive. Newcomers in an industry may be expected to be uninformed concerning much of its organization. When in addition their volume of business is small, it is also conceivable that there is not much incentive to become informed.

TABLE 6.—NUMBER OF PRODUCERS BY AVERAGE DAILY DELIVERIES

Full-time Producers, 1935

Average Daily Deliveries		Producers Selling to Group I Dealers		Producers Selling to Group IV Dealers	
Pounds	20-Quart Jugs	Number	Percent	Number	Percent
0– 43	1	2	.9	18	6.7
44– 86	2	24	10.7	47	17.6
87–129	3	31	13.8	69	25.9
130–172	4	35	15.6	54	20.2
173–215	5	31	13.9	23	8.6
216–258	6	25	11.2	22	8.3
259–301	7	22	9.8	10	3.7
302–344	8	16	7.1	5	1.9
345–387	9	16	7.1	10	3.7
388–430	10	8	3.6	2	.8
431–473	11	8	3.6	1	.4
474 and over	12	6	2.7	6	2.2
Total		224	100.0	267	100.0

TABLE 7.—AVERAGE BUTTERFAT TEST OF PURCHASES FROM FULL-TIME PRODUCERS, BY DEALERS IN GROUP I AND GROUP IV.

Dealer	Number of Producers	Butterfat Test	Dealer	Number of Producers	Butterfat Test
Group I			Group IV		
A	33	4.020	M	36	4.070
B	*	*	N	122	3.706
C	21	3.875	O	50	3.890
D	164	3.880	P	45	3.720

*No data.

Characteristics of the Industry Hinder Rapid Adjustments in Production

Those persons familiar with the milk business appreciate only too well the significant features of dairy farm production. Outstanding, of course, is its seasonality — heavy production in the so-called flush months in the spring, and light production in the short months in the late fall. In addition to its seasonal variations, dairy production conforms to a cyclical movement of 14 to 16 years' duration.

Milk production requires its special facilities, many of which are not adaptable to other farm enterprises. These are a part of the business but they have been required by boards of health rather than introduced by the producers in order to hold or enlarge their market. These are the rigidities of the supply. Because of them, to a large extent, the productive activity of a given milkshed changes slowly.

Since milk production is not adapted to rapid shifts, extreme variations in price might supposedly be controlled by adjustments in the supplies of the distributing agencies in the market. This change would be accomplished by some producers shifting to dealers having higher product-costs. This process should be a continuous one, the intensity of the activity varying with the degree of price variation. Since wide differences in price continue to prevail, the only conclusion possible is that adjustments have not been and are not taking place.

Extreme variation in price may have a number of effects: (1) Producers receiving the lower prices may be forced out of business and the variation narrowed. (2) Producers receiving the lower price may enter the market on a cut-price basis; all prices may be reduced to a point at and beyond which some producers will be forced out of the dairy business and the variation narrowed. (3) Under the stress of a price war the industry may make concessions designed to protect the bulk of its supply. (4) Under the pressure of a serious threat to its regular milk supply, government with the joint support of producers and consumers may be expected to promulgate such edicts as will protect it. In recent years variation in price has produced all of these effects.

Since June 1934, the Massachusetts Milk Control Board has been a party to milk distribution in Massachusetts markets, with the general objective of achieving market stability. In the statement of its objective, the Board has established several general practices. Among these are:

1. Uniform class prices to all dealers in a market.
2. Fair treatment of producers by dealers:
    (a) Weights and tests to be checked to assure accuracy.
    (b) Reasonable notice to be given to producer before discontinuance of purchases (market protection).
    (c) Deductions for services to be equitable.
    (d) Payment for purchases to be made in full and promptly.
3. Elimination of unethical practices among dealers in city distribution, chiefly discounts, rebates, or "free services."

The most serious threat to market stability — variation in dealers' product costs — has not been directly attended to by the Milk Control Board nor by the industry. Presumably under the Use-Plan method of purchasing milk, with all dealers on an agency basis, variations in product-cost would be directly reflected in producers' prices with no advantages accruing to dealers as a result of the variations. So far as producers' f. o. b. the market prices are concerned, the transfer in price operates as conceived. The transportation charge which dealers deduct for providing or having provided the cartage service is only partially supervised; consequently, competitive advantages continue to exist among the dealers in the variations in their product-cost.

The more severe effect of the variations rests on the producers' f. o. b. the market price. This may be eliminated or reduced in a number of ways. Elimination may be achieved through the medium of a market pool operated by the Control Board, a producers' monopoly, a dealers' association, or joint efforts of all or of any combination of them. The market pool, however, which assures producers the same f. o. b. market prices for standard milk, introduces questions relative to producers' rights in the market and the effect on the total supply of a price superior or inferior to that currently being received.

In May 1935, 62.6 percent of the full-time producers sold dealers whose product-costs, i. e., producers' f. o. b. prices, were below the market average. A third of this group, which is 20.9 percent of all the full-time producers, sold dealers in group IV. Had dealers' product-costs been determined on a market-pool basis, producers selling dealers in group IV in May 1935, other things remaining unchanged, would have received 37 cents more per hundredweight for their product than they did. This difference is 15.5 percent over their weighted average price. The increase over the price paid by any individual dealer ranged from 27 to 56 cents per hundredweight. Producers in this group delivered 24.6 percent of the supply on the market in May.

Dealers in group I during this month had product-costs that were 20.7 cents, or 7.5 percent, above the pool cost. Of the total number of full-time producers, 26.8 percent sold to these dealers. These producers represented 72.6 percent of all the producers who sold dealers having product-costs better than average.

Dealers in group I handled 23.8 percent of the deliveries to the market in May, and dealers in group IV handled slightly more, or 24.6 percent.

Analysis of relationships in terms of annual data shows but minor changes compared with those existing in May. The pool price was 30.5 cents, or 12.1 percent, higher than the product-cost of dealers in group IV, and 12.2 cents, or 4.1 percent, below the product-cost of dealers in group I. The proportion of the total volume of milk which was handled by each of the two groups changed slightly. Dealers in group IV handled 21.9 percent and in group I, 24.7 percent of the total. The ratios of full-time producers remained unchanged.

It is probable that producers selling to these two groups of dealers would show the most marked response to a market-pool price basis. The size of the variation between prices necessary to stimulate action has not been determined, nor does it appear certain that it can be determined exactly. It is probable, however, that the greater the deviation from a central price, the greater the incentive to make adjustments.

Although it has been and can be demonstrated that a market pool will eliminate the variations in dealers' product-costs, it does not follow that the market pool is desirable.

The producers supplying dealers whose product-costs deviate most widely from the pool cost would probably react most promptly to the establishment of a market pool. The course which their reaction would follow is a matter of speculation. Producers selling to dealers who had a low product-cost had low average daily deliveries of milk. Product-cost may have been a factor tending toward a small volume of production. It is more probable, however, that lack of adequate barn space, lack of carrying capacity, and pressure of other enterprises kept the volume of production down. Should this assumption be reasonable, an increase of 30.0 cents per hundredweight would not greatly affect the deliveries of this group. Producers selling to dealers having a high product-cost were and are probably very dependent on their dairy business for their income. Their large volume of average daily deliveries indicates a larger business. It is not inconceivable that, should their price be lowered and their unit profits reduced, they might increase their volume of average daily deliveries somewhat in order to maintain their total income.

One objection to a market pool for the Springfield–Holyoke–Chicopee area is not so much the effect it may have on the productive activity of the existing shed as the attraction it would be to milk not now a part of that supply. The drawing power of the product-cost in the Springfield market area would, of course, depend on its relation to product-costs in other markets that secure their supplies from the same or contiguous sheds. Response to the drawing power would depend on the freedom of producers to shift from other markets; the ability of producers to establish the necessary contacts; and the probable net farm prices that would be received. It is improbable that individual producers would or could change easily from one market to another, the principal hindrance being the absence of transportation accommodations. Groups of producers, however, would be able to secure the necessary cartage and the significant shifts would be made by groups, if at all.

The chief disadvantage to a market pool is its probable long-time influence. The immediate result of the pool would be a substantial price increase for a block of producers in the shed and a small decrease for a slightly smaller group of producers. If no protection is established against shifting supplies from other markets, the volume of milk on the market and in the pool will probably increase. The pool product-cost will be under constant pressure and will be forced down toward the product-cost which would have applied to dealers in group IV. As a result of the process, for example, producers selling dealers in group IV are temporarily better off and producers selling dealers in group I are placed at a slight loss. The long-time effect is to force product-costs to the lower level for all.

Alternatives to a Market Pool

Instead of risking the undesirable results of a market pool, it would be better to minimize the variations in product-cost than to attempt their complete elimination. This approach[4] might raise the price to all the producers in the milkshed, although it could be handled so that the average increase would be very small. Since variations in dealers' product-costs would continue to exist, the attractiveness of the Springfield–Holyoke–Chicopee area would be on a distributor basis rather than market-wide, and the apparent advantage over other markets would be appreciably lessened.

Producers selling to dealers having a low product-cost would receive the largest increase in price. It would be producers with similar marketing arangements in other markets to whom the attraction would be greatest. Their disadvantage could be partly reduced by determining the product-costs of their buyers in the same manner as that used for Springfield dealers.

Since the establishment of the classified plan for buying milk, the dependence of market stability upon a narrow spread between class prices has been recognized.[5] The opportunity for dealers to buy milk more advantageously from one group of producers than another exists when the Class I price is substantially higher than the Class II price, and the ratios of sales to purchases vary considerably among dealers.

A spread that is relatively uniform as well as narrow would promote stable market conditions. Such a characteristic depends on the pricing techniques in operation. In Massachusetts markets where only two uses are recognized for price making purposes, the determination of prices is relatively simple. The price of milk going into other than fluid channels, i. e., surplus or Class II, is based on its market value in cream or butter. The Class II price is a formula price and the formula has been modified as the occasion seemed to warrant.

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[4] The price for Class II milk should be a function (percentage) of the price for Class I milk.

[5] Varney, H. R. This Milk Problem. Vt. Ext. Circ. 95, p. 79.

The pricing techniques have given little uniformity to the spread between prices for fluid and for surplus milk. Any relationship between them was mechanically controlled. As the two series got seriously out of line, one of the following methods was used to restore the balance:

(a) A change was made in the method of computing the surplus price; or

(b) An adjustment was made in the price of Class I milk.

It has probably been the experience of the market that the corrections were not introduced until a certain amount of damage had been done to the market.

The Relationship Between the Price for Class I and Class II Usage

Two types of important relationships prevail between the price for milk disposed of as Class I or as Class II. The seasonal relationship is the basic one to be expected during a production period. The cyclical or long-time relationship would indicate the trend of the relationship but more significantly the degree or efficiency with which the pricing mechanism has been developed or employed.

Examination of the Fluid-Surplus[6] price ratio in the 181-200 mile zone of the Boston milkshed indicated an upward trend during the 15-year period 1921–1935 inclusive; a trend which was very sharp during the 5-year period 1931–1935. (See table 8 and figure 6.) Whether the changes in the ratio were due to adjustments in the Class I price or in the Class II price or both should not be ignored. The significance to be derived from a study of the ratios is, however, the constantly widening spread between the Class I price and the Class II price. The period during which a high ratio prevailed was the period of greatest market instability. Whether the price mechanism was faulty or was unwisely employed is debatable. The results, however, have been unsatisfactory.

Since the ratio between the prices is a good measure of the relative spread between them and also of its stability, it would seem a logical step to use this ratio in determining the Class II price; particularly since the market value of native cream is appreciably greater than that of western, on which the market is based. The ratio should conform to seasonal considerations, and be lower in the short season than in the flush. Adapting average market experience of the past 15 years, the ratio periods would be November to April inclusive and May to October inclusive. The ratio showed only slight monthly variation during the flush months, and with the exception of January, only slightly greater variation during the short months. The two periods were so very definitely marked off that there could be little question as to the desirability of using them.

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[6] Based on data in N. E. M. P. A. handbook. Fluid—Surplus=Class I— Class II.

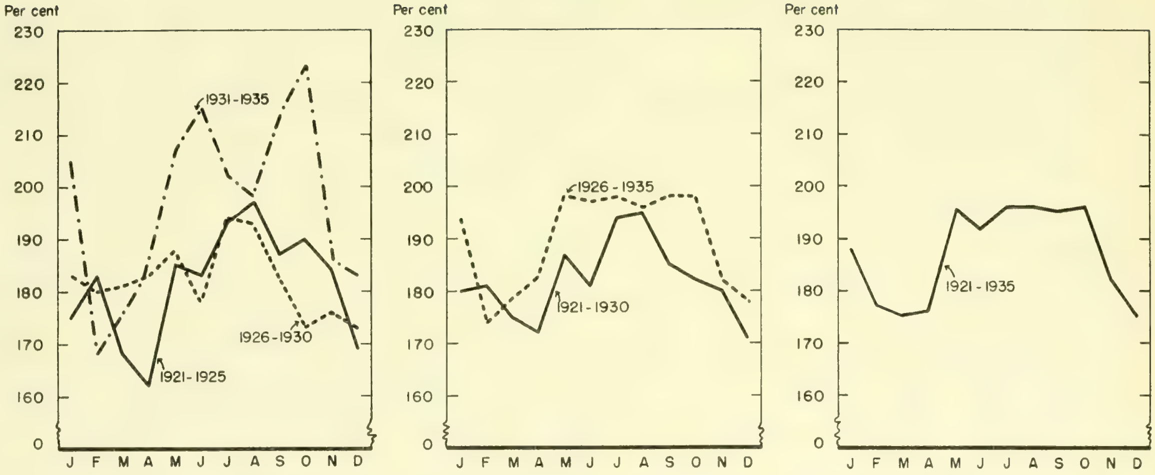

Figure 6. The Relationship Between Fluid and Surplus Prices in the 181-200 Mile Zone of the Boston Milkshed
By Five, Ten, and Fifteen Year Periods, 1921-1935

TABLE 8.—RATIO OF FLUID TO SURPLUS PRICES IN THE 181-200 MILE ZONE OF THE BOSTON MILKSHED, 1921-1935

Month	5-Year Averages			10-Year Averages		15-Year Averages
	1921-25	1926-30	1931-35	1921-30	1926-35	1921-35
January	175	183	205	180	194	188
February	183	180	168	181	174	177
March	168	181	176	175	179	175
April	162	183	183	172	183	176
May	185	188	207	187	198	194
June	183	178	215	181	197	192
July	193	194	202	194	198	196
August	197	193	198	195	196	196
September	187	182	214	185	198	195
October	190	173	223	182	198	196
November	184	176	186	180	182	182
December	169	173	183	171	178	175

The method employed by the New York Market Administrator is a functional one. The prices payable for purchases disposed of in the several classes are dependent on the butter market. An arbitrary schedule of prices based on butter has the advantage of bearing a very definite relationship to competitive conditions which would minimize any tendency to overvalue the product arbitrarily priced. The principal objection to a butter price basis — frequent variation — is overcome by associating class prices with butter price changes at five-cent intervals.

The specific ratios to be used should bear some relationship to the recognized average value of native cream. The average ratios developed during the past 15 years when various formulas were employed were approximately 196 during the flush season and 175 during the short season. Recognizing that the value of native cream is probably greater than is accounted for by current formula methods of pricing, the seasonal ratio might well be 175 during the flush season and not more than 150 during the short season. Using this method, a Class I price of $3.00 would result in a Class II price of $1.71 during the flush season and $2.00 during the short season. If these prices are too high, the Class I price could be lowered, with proportionate reduction in the Class II. The higher value for native cream would be taken care of and the uniform spread maintained.

Summary

The milk industry can perform its most effective service under conditions of relative market stability. Conditions in various Massachusetts secondary areas are not conducive to market orderliness. Among these conditions are uneven distribution of fluid outlets among dealers, rigidities in producer–distributor relationships, and the absence of reasonable relationships between the price payable for milk disposed of as fluid and as surplus.

So long as the advantages accruing to distributors as a result of superior personal contact are fully returned to their producers and so long as they are maintained by fair methods, these advantages should not be arbitrarily diminished.

The disadvantages suffered by all producers but mostly by producers with inferior sales' outlets should be minimized by the development and application of a logical pricing technique based on "normal" class price relationships.

APPENDIX

TABLE I. — PERCENTAGE OF PURCHASES DISPOSED OF IN CLASS I SALES BY DEALERS* WHOSE PRODUCT-COSTS WERE ABOVE THE MARKET AVERAGE

Selected Months, 1935

Dealer	February	May	August	November
A	95.1	83.1	89.8	99.2
B	82.3	74.6	80.8	87.2
C	93.9	78.9	87.7	90.5
D	93.0	79.8	72.6	88.3
E	91.5			
F	81.0	69.6		
G	92.2	97.2	94.6	97.6
H			80.0	91.1
I	92.4			
L	83.5			
Q		85.7	90.8	
R	97.6	85.2	84.6	85.0
S	93.2	71.7	81.8	90.8
T	84.2	75.5	88.8	103.1
U	78.6	72.2		
Percent of Market	82.1	68.6	70.5	84.8

*Flat Plan dealers excluded.

TABLE II. — NUMBER OF PRODUCERS SELLING TO DEALERS WHOSE PRODUCT-COSTS WERE ABOVE OR BELOW THE MARKET AVERAGE

Selected Months, 1935

Dealer	Producers Selling to Dealers with Product-costs Above the Average											
	February			May			August			November		
	Full-time	Part-time	All	Full-time	Part-time	All	Full-time	Part-time	All	Full-time	Part-time	All
Flat Plan												
AA	5	3	8	3	1	4	3	1	4	3	1	4
BB	3	0	3	3	0	3	3	0	3	3	0	3
CC	10	3	13	10	4	14	10	5	15	14	6	20
DD	7	0	7	7	0	7	8	1	9	7	1	8
EE	3	0	3	3	0	3	3	1	4	3	0	3
FF	8	1	9	11	2	13	11	3	14	10	3	13
GG	1	1	2	1	1	2	2	1	3	1	0	1
HH	9	1	10	11	4	15	10	4	14	23	2	25
II	2	0	2	2	0	2	2	0	2	2	0	2
JJ	10	1	11	10	0	10	9	0	9	10	0	10
KK	1	0	1	1	0	1	1	0	1	1	0	1
LL	1	0	1	1	0	1	1	0	1	1	0	1
Total	60	10	70	63	12	75	63	16	79	78	13	91
Use and Mixed Plans												
A	37	3	40	36	1	37	35	2	37	34	1	35
B				13	2	15	13	2	15	13	2	15
C	23	2	25	23	2	25	23	2	25	24	3	27
D	169	5	174	169	5	174	167	3	170	181	3	184
E	24	8	32									
F	18	1	19	20	1	21						
G	18	8	26	14	9	23						
H							30	5	35	29	4	33
I				87	0	87						
L	28	9	37									
Q				25	1	26	26	5	31			
R	9	1	10	8	0	8	8	1	9	12	6	18
S	8	1	9	5	0	5	7	0	7	9	1	10
T	7	0	7	7	0	7	7	0	7	7	0	7
U	9	2	11	7	0	7						
Total	350	40	390	414	21	435	316	20	336	309	20	329
Total Above Average	410	50	460	477	33	510	379	36	415	387	33	420
	Producers Selling to Dealers with Product-costs Below the Average											
E				19	11	30	12	11	23	22	6	28
F							19	2	21	24	6	30
G							14	8	22	12	1	13
H				32	5	37						
I	85	0	85				92	6	98	91	6	97
J	142	13	155	138	7	145	139	8	147	138	11	149
K	38	1	39	37	1	38	37	1	38	37	1	38
L				26	6	32	23	9	32	20	7	27
M	38	1	39	37	0	37	37	0	37	36	0	36
N	140	14	154	153	20	173	149	32	181	151	35	186
O	60	4	64	61	4	65	59	4	63	58	2	60
P	67	13	80	72	16	88	72	19	91	60	13	73
Q	24	1	25							27	4	31
U							7	0	7	9	1	10
W	216	28	244	220	25	245	197	20	217	191	9	200
Total Below Average	810	75	885	795	95	890	857	120	977	876	102	978

TABLE III.—NUMBER OF PRODUCERS SELLING TO DEALERS WHOSE PRODUCT-COSTS WERE ABOVE OR BELOW THE MARKET AVERAGE—SUMMARY

Selected Months, 1935

Classes of Producers	February			May			August			November		
	Number	Percent	Percent of All Producers	Number	Percent	Percent of All Producers	Number	Percent	Percent of All Producers	Number	Percent	Percent of All Producers
Total producers	1,345			1,400			1,392			1,398		
Producers selling to dealers with product-costs above average												
Full-time	410	89.1	30.5	477	93.5	34.1	379	91.3	27.2	387	92.1	27.7
Part-time	50	10.9	3.7	33	6.5	2.4	36	8.7	2.6	33	7.9	2.3
Total	460	100.0	34.2	510	100.0	36.4	415	100.0	29.8	420	100.0	30.0
Producers selling to dealers with product-costs below average												
Full-time	810	91.5	60.2	795	89.3	56.8	857	87.7	61.6	876	89.6	62.7
Part-time	75	8.5	5.6	95	10.7	6.8	120	12.3	8.6	102	10.4	7.3
Total	885	100.0	65.8	890	100.0	63.6	977	100.0	70.2	978	100.0	70.0

TABLE IV. — NUMBER OF PRODUCERS ACCORDING TO THE LENGTH OF TIME THEY WERE SELLING IN THE SPRINGFIELD MARKET

Selected Months, 1935

Month	Total Number of Producers	Full-time		Part-time	
		Number	Percent	Number	Percent
February	1,345	1,220	90.7	125	9.3
May	1,400	1,272	90.6	128	9.4
August	1,392	1,236	88.8	156	11.2
November	1,398	1,263	90.3	135	9.7

TABLE V. — VOLUME OF MILK HANDLED BY DEALERS WHOSE PRODUCT-COSTS WERE ABOVE OR BELOW THE MARKET AVERAGE

Monthly, 1935

	Product-Costs Above Average			Product-Costs Below Average		
Month	Number of Dealers	Pounds	Percent of Market Total	Number of Dealers	Pounds	Percent of Market Total
January	22	2,742,655	43.0	7	2,113,284	33.1
February	20	2,277,667	38.8	10	3,162,402	53.9
March	25	2,781,757	40.6	10	3,752,240	54.9
April	25	2,905,776	42.0	10	3,693,345	53.5
May	25	3,688,143	48.1	10	3,689,034	48.1
June	24	3,626,343	47.5	11	3,715,491	48.7
July	23	3,334,480	46.9	12	3,523,295	49.6
August	22	2,638,904	37.5	13	4,099,273	58.2
September	22	2,438,871	37.0	13	3,836,677	58.4
October	21	2,415,886	36.5	14	4,030,610	60.9
November	21	2,147,305	35.7	14	3,591,142	59.8
December	20	2,241,864	35.0	15	3,841,769	60.0
Year	17	29,035,376	35.8	14	47,652,150	58.8

TABLE VI. — VOLUME OF MILK HANDLED BY DEALERS WHOSE PRODUCT-COSTS WERE ABOVE OR BELOW THE MARKET AVERAGE

Dealer Buying Plan	Product-Costs Above Average		Product-Costs Below Average	
	Volume (Pounds)	Percent of Total	Volume (Pounds)	Percent of Total
Use	20,541,746	26.8	43,541,338	56.8
Mixed	3,406,443	4.4	4,110,812	5.4
Flat	5,087,187	6.6		
Total	29,035,376	37.8	47,652,150	62.2

TABLE VII. — PERCENTAGE OF AVERAGE DAILY PURCHASES SOLD AS CLASS I BY DEALER GROUPS

Monthly, 1935

Month	USE PLAN			MIXED PLAN			INADEQUATE DATA			FLAT PLAN
	Purchases	Sold as Class I		Purchases	Sold as Class I		Purchases	Sold as Class I		Purchases or Sales
		Pounds	Percent		Pounds	Percent		Pounds	Percent	
January	173,125	142,563	82.3	10,539	9,606	91.1	13,916	12,985	93.3	12,900
February	175,965	141,598	80.5	10,960	9,729	88.8	14,270	12,881	90.3	13.220
March	185,573	139,331	75.1	11,382	9,867	86.7	15,350	12,031	78.4	13.817
April	194,826	139,256	71.5	11,257	9,195	81.7	15,908	12,814	80.6	13.885
May	211,116	138,075	65.4	11,791	9,397	79.7	15,564	12,441	79.9	15,065
June	218,023	135,839	62.3	12,123	9,623	79.4	15,721	12,151	77.3	14,581
July	197,166	132,499	67.2	11,007	9,164	83.3	14,644	12,341	84.3	13,044
August	191,960	129,672	67.6	11,090	9,265	83.5	14,653	12,053	82.3	14,307
September	184,463	130,819	70.9	10,733	9,175	85.5	15,132	12,288	81.2	13,984
October	183,313	134,069	73.1	10,681	9,362	87.7	15,674	13,458	85.9	13,955
November	166,849	135,288	81.1	10,521	9,089	86.4	14,306	13,165	92.0	13,900
December	171,237	128,975	75.3	10,679	9,008	84.4	15,192	12,763	84.0	14,536
Average	187,854	135,621	73.7	11,063	9,372	84.7	15,031	12,612	83.9	13,937

TABLE VIII. — MONTHLY INDEX OF AVERAGE DAILY SALES ACCORDING TO BUYING PLANS
1935=100

Month	Use Plan	Flat Plan	Mixed Plan
January	105.1	92.5	102.5
February	104.4	94.9	103.8
March	102.7	99.1	105.3
April	102.7	99.6	98.1
May	101.8	108.0	100.3
June	100.2	104.6	102.7
July	97.7	93.6	97.8
August	95.6	102.7	98.9
September	96.5	100.3	97.9
October	98.9	100.1	99.9
November	99.8	99.7	96.9
December	95.1	104.3	96.1

TABLE IX. — PERCENTAGE DISTRIBUTION OF PURCHASES AND SALES OF MILK AMONG DEALERS ACCORDING TO BUYING PLAN
Monthly, 1935

Month	Purchases				Sales			
	Use Plan	Flat Plan	Mixed Plan	Data Inadequate	Use Plan	Flat Plan	Mixed Plan	Data Inadequate
January	82.3	6.1	5.0	6.6	80.0	7.3	5.4	7.3
February	82.1	6.1	5.1	6.7	80.0	7.2	5.5	7.3
March	82.1	6.1	5.0	6.8	80.0	7.9	5.6	6.9
April	82.6	5.9	4.8	6.7	80.0	7.9	5.3	7.3
May	83.3	5.9	4.7	6.1	79.0	8.6	5.4	7.1
June	83.7	5.6	4.7	6.0	78.9	8.4	5.6	7.1
July	83.6	5.5	4.7	6.2	79.3	7.8	5.5	7.4
August	82.7	6.2	4.8	6.3	78.4	8.7	5.6	7.3
September	82.2	6.3	4.8	6.7	78.7	8.4	5.5	7.4
October	82.0	6.2	4.8	7.0	78.5	8.2	5.5	7.9
November	81.2	6.8	5.1	7.0	78.9	8.1	5.3	7.7
December	80.9	6.9	5.0	7.2	78.0	8.8	5.5	7.7
Average	82.4	6.1	4.9	6.6	79.1	8.1	5.5	7.4

TABLE X. — DEALERS' EXPENDITURES FOR AND PRODUCT-COST OF MILK, 1935

Dollars	Number of Dealers	Total Expenditures (Dollars)	Product-Cost (Dollars)	Range among Dealers (Dollars)
0– 25,000	5	89,594.72	2.90	.40
25,001– 50,000	6	207,775.07	2.80	.38
50,001–100,000	7	496,806.33	2.50	1.17
100,001 and over	4	1,124,152.91	2.74	.35
Totals	22	1,918,329.03	2.69	1.21

TABLE XI.—CLASS I AND CLASS II PRICES AND THE CLASS I–CLASS II PRICE RATIO
Monthly, 1935

Month	Class I Price (Dollars)	Class II Price (Dollars)	Ratio	Percent Class II	Product-Cost (Dollars)
January	2.90	1.67	1.73	16	2.70
February	2.90	1.87	1.55	18	2.71
March	3.22	1.80	1.78	23	2.89
April	3.37	1.82	1.85	26	2.96
May	3.37	1.37	2.45	31	2.74
June	3.37	1.07	3.14	34	2.58
July	3.37	1.22	2.76	30	2.75
August	3.37	1.26	2.67	29	2.75
September	3.37	1.23	2.73	26	2.81
October	3.33	1.37	2.43	24	2.85
November	3.25	1.76	1.84	17	2.99
December	3.25	1.80	1.80	22	2.93

TABLE XII. — AVERAGE DAILY VOLUME HANDLED BY PRODUCER OPERATORS
January, 1935

Pounds	Producer-Distributors	Producer-Dealers
0– 99	2	1
100–199	4	1
200–299	4	3
300 and over	5	5
Total	15	10

TABLE XIII. — AVERAGE DAILY COST OF MILK TO DEALERS*
Monthly, 1935

Month	Cost of All Milk (Dollars)	Average Daily Cost (Dollars)	Index of Average Daily Cost†
January	176,368.05	5,689.29	88.4
February	162,937.70	5,819.20	90.4
March	202,793.51	6,541.72	101.6
April	209,883.06	6,996.10	108.7
May	216,060.40	6,969.69	108.3
June	202,137.83	6,737.92	104.7
July	199,974.99	6,450.80	100.2
August	198,294.47	6,396.59	99.4
September	189,230.72	6,307.69	97.9
October	198,125.13	6,391.13	100.1
November	198,237.73	6,607.92	102.6
December	192,302.91	6,203.31	96.3

*Flat Plan Dealers not included.

†Average Daily Cost for the year=100.

TABLE XIV. — PERCENTAGE OF ANNUAL VOLUME PURCHASED BY THE FOUR GROUPS AND THE RELATIVE IMPORTANCE OF THE LARGEST DEALER IN EACH GROUP

Group	Pounds of Milk Purchased	Percent of Total	Largest Dealer's Percentage of Group Total
I	20,541,746	31.5	72.9
II	12,682,796	19.4	72.6
III	13,796,151	21.1	64.4
IV	18,183,417	27.8	47.2

TABLE XV. — RANGE IN PRICES OF FOUR HIGHEST AND FOUR LOWEST DEALERS
Monthly, 1935
(Dollars per hundredweight)

	Group I—Four Highest			Group IV—Four Lowest		
Month	Maximum	Minimum	Range	Maximum	Minimum	Range
January	2.84	2.75	.09	2.60	2.25	.35
February	2.85	2.82	.03	2.65	2.27	.38
March	3.18	3.03	.15	2.76	2.34	.42
April	3.14	3.04	.10	2.75	2.40	.35
May	3.02	2.88	.14	2.47	2.19	.28
June	2.95	2.78	.17	2.23	1.77	.46
July	3.09	2.81	.28	2.54	2.31	.23
August	3.11	2.94	.17	2.58	2.32	.26
September	3.10	2.94	.16	2.59	2.40	.19
October	3.18	3.00	.18	2.58	2.44	.14
November	3.21	3.07	.14	2.74	2.47	.27
December	3.17	2.93	.23	2.69	2.42	.27

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MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

Bulletin No. 366 November 1939

Towards a Perfect Milk Market

By J. Elizabeth Donley

The problem of providing an economical and constant supply of milk to our municipalities is of much concern to both producer and consumer. This study of the Worcester market is intended to contribute to a solution.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

TOWARDS A PERFECT MILK MARKET[1]

By J. Elizabeth Donley, Research Assistant in Agricultural Economics and Farm Management

Not so many years ago the farmer drove up to his customer's home, ladled out milk into a can or jug on the steps, then drove on to the next house. This milk probably cost the consumer six or eight cents a quart. Now, milk usually travels miles and miles from the time it leaves the farmer until it reaches the consumer in a bottle, and moreover, the cost is about twice as great.

Many a consumer still remembers those days and now and then when he pays for his milk thinks "they" are putting something over on him. He realizes that the general cost of living is higher, but not that much higher. He realizes also that someone else has come into the picture — the dealer — knows he also must be paid, but still and all, it does not seem quite fair to pay so much per quart for one of life's essential foods. He gets emotional about it.

The farmer, on the other hand, also remembers those days and invariably thinks that the old days were better. He feels oppressed by the higher cost of commodities which he purchases, for he receives no more now for his milk than in the old days, and often not nearly so much. How can he ever make any profit?

And then there is the dealer — the newcomer. Modern urban life requires more milk, in a more sanitary condition. This necessitates bringing it in from greater distances and pasteurizing it, as well as taking care of any surplus. This is the dealer's job, plus that of distributing the milk at convenient times in convenient form to the consumer. The dealer also is unhappy, for the farmer complains that he is paid too little for his product and the consumer complains that he is charged too much. These complaints make excellent copy for newspapers and hence the complaints sound even louder.

In 1935 the New England Research Council decided to tackle this vast problem in this section of the country to see if, after the facts had been gathered and pondered over, some solution might be made.

In Massachusetts two secondary markets, Springfield and Worcester, have been and are being studied as a part of this long-range project. In Springfield much detailed work has been done in all phases of milk marketing, in an effort to bring some order to this market. Only the supply side, however, of the Worcester market has been mapped and analyzed, and that more or less superficially, for the results seem to justify this approach. As the work which led to this conclusion is revealed, it will be apparent that the Worcester market is abnormal in one respect — it is quite normal. There are, to be sure, some channels through which the supply of milk is obtained which might be improved upon, but this is true of any market, and unless we wish more government control, those channels of supply will remain as they are. Cooperation can do much, but only so much. The consumer is justified in disliking to pay for duplication of service, but in Worcester there is very little duplication in getting the milk to the market.

The distribution of milk to the consumer in Worcester has not been studied, but if there is no more duplication in that phase than there is in obtaining the milk from the farmer, the consumer should decide that he is not paying for extra services and that his milk is not expensive, but rather is an economical food of which more should be consumed.

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[1] The data for this bulletin were collected by Chester Smith for his thesis entitled, Some Economic Aspects of Marketing Fluid Milk in Worcester, Massachusetts, submitted for the Master's Degree at Massachusetts State College in 1937.

In 1934 the Massachusetts Legislature decided to do something about the milk situation and in that year established the Milk Control Board. Briefly, it is empowered to set schedules of producer and retail prices in response to a sufficiently large producer petition. It has authority to investigate dealers' records, summon offenders to hearings, and inflict penalties necessary to the proper enforcement of price schedules. The temporary law under which the Board operated was extended by an act of legislature in 1936; but since the first milk-marketing law, the Worcester market, along with other secondary markets in the Commonwealth, has been under the Milk Control Board's jurisdiction.

To facilitate the Board in its work, the State has been divided into "marketing areas" of similar conditions, the city of Worcester and surrounding towns constituting Area 8. Separate price schedules are issued for each area according to local needs, and producers are paid according to the area in which their milk is marketed if such area is not the area in which they live. During 1935 the price of Class I milk to the producer was changed twice. On March 10 it was raised from six and one-half to seven and one-quarter cents per quart, where it remained until October 20, when it was reduced to seven cents per quart.

The Milk Control Board has carried on other activities besides enforcement of price schedules. It has forced some dealers to make up payments that have been in arrears. A few dealers have been required to reduce excessive trucking rates. The Board has attempted to prevent dealers from dropping producers without reasonable notice and cause, and has required some dealers to keep adequate records of their business.

The Board is supported by a dealer license fee of $5.00 and an assessment of two cents per hundredweight of all milk sold. The full amount of the assessment is paid by the dealer, who is allowed to deduct half of this amount, or one cent per hundredweight, from producers' checks.

The Massachusetts Milk Control Board furnished the basic data for this study: records of milk-dealer payroll audits for the calendar year 1935. For all agencies licensed to distribute milk in the city of Worcester, records should have included the following:

1. Dealer purchases of milk from producers by semi-monthly pay periods.
2. Milk purchases divided between base and surplus for rating-plan dealers.
3. Gross Class I, Class II, and blended prices paid for milk by semi-monthly pay periods.
4. Net amounts (dollars) received for milk by producers by semi-monthly pay periods.
5. Records of deductions.
    a. Milk Control Board assessments.
    b. Can charges.
    c. Cooperative association fees.
    d. Transportation rates.
    e. Other deductions.
6. Total purchases by dealers by semi-monthly pay periods and Class I and Class II division of sales.

The above-outlined price and purchase information was incomplete for certain dealers, but as far as possible the missing data were obtained from actual payroll records through personal contacts with such dealers. When data for one or two months were unavailable, interpolations were made. Other omissions have necessitated the study of a large sample rather than absolute tabulation.

Figure 1, which geographically locates producers, has been used as a basis for showing numerous economic variations among producers in the milkshed. This map shows the location of 617 producers, or approximately 90 percent of the total number of producers, who shipped 90 percent of the total volume of milk. There were 31 additional producers' names listed in the files of the Massachusetts Milk Control Board, but no data concerning them. These producers represented such a small proportion of the entire market that their omission could have little effect on the reliability of the study of variations of all Massachusetts milk entering the Worcester market.

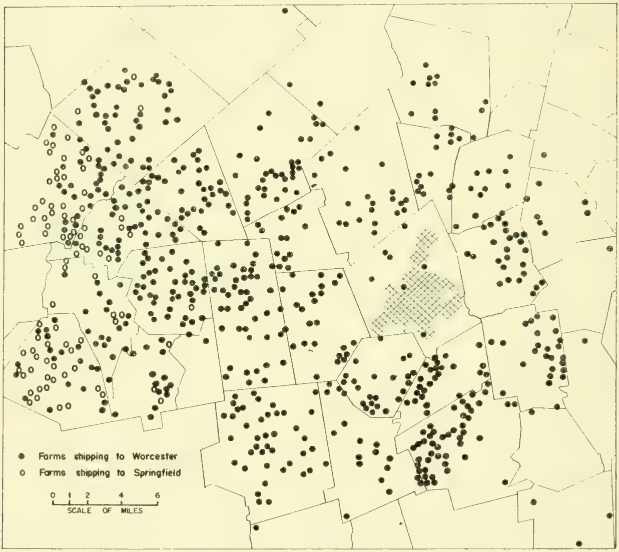
● Farms shipping to Worcester
○ Farms shipping to Springfield
0 1 2 4 6
SCALE OF MILES

Figure 1. Location of Farms in the Worcester Milkshed, 1935.

Worcester as Related to Other Markets

Worcester is the third largest city in New England, being exceeded only by Boston and Providence. The 1935 census reported a population of 190,471, a decrease of 2.5 percent from the peak reached in 1930. The city is centrally located, serving as a shopping center for approximately 400,000 people. The population is further increased during a large part of the year by the presence of four colleges and two preparatory schools. There are 600 industrial establishments of such diversity that employment is fairly stable except in times of extreme business inactivity.

Worcester is 40 miles west of Boston, the only primary market in New England, and about 190 miles northeast of New York City, another primary market. Although 3.5 percent of Worcester's milk came from a country plant in Hoosick, New York, on the eastern edge of New York City's supply area, the Worcester market was not influenced to any great extent by this milkshed because of the intervening secondary markets of Springfield, Chicopee, Westfield, Holyoke, and Pittsfield.

The Worcester market is directly related to the Boston market in at least three respects. (1) Milk production for Worcester from territory east of the city was practically confined to three nearby towns.[2] (2) The Boston market is large and near enough to the entire Worcester supply area to enable some Worcester producers to compete occasionally in that market. (3) Two of the largest milk-distributing concerns in New England with their major business operations in Boston operate branch plants in Worcester.

The study of secondary milk market supplies in 1932 by the Massachusetts Agricultural Experiment Station[3] recognized 29 such markets.[4] The Worcester supply area was influenced by the size and location of 10 of these other secondary markets, all of which except Springfield were much smaller markets.

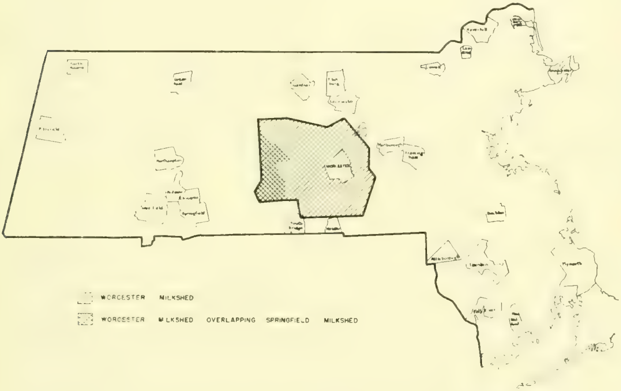

Figure 2. Location of 29 Secondary Milk Markets and Worcester Milkshed, 1935.

The smaller markets bordering Worcester formed the links of an imaginary chain describing a semi-circle east of the city and acted collectively as a natural boundary of the Worcester milkshed. Figure 2 indicates that the supply area for the city did not extend far enough to include any of these smaller markets, although the outer edges of the milksheds overlapped somewhat, making possible some producer choice between markets. A large part of the milk business of these markets was of the producer–distributor type. Except for Fitchburg, and possibly Gardner and Framingham, these towns were not large enough to enable dealers buying from wholesale producers to exert much influence on the Worcester market. Thirteen of the 56 milk dealers[5] selling in Worcester in 1935 were located outside of the city in surrounding towns. Of these 13, two were in Boylston and two in West Boylston. Their location enabled them to be potential, if not actual, competitors in the Clinton market. The activities of a Webster dealer in Worcester accounted for the small amount of Connecticut milk that was sold in Worcester.

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[2] See figure 1.

[3] Lindsey, A. H., Sources of Milk Supply in Twenty-nine Secondary Markets, Mimeographed report, Mass. Agr. Exp. Sta., March 1934.

[4] See figure 2.

[5] Does not include producer–dealers and producer–distributors.

Springfield, with a population of about 150,000 in 1935, although located 50 miles west of Worcester, was large enough to bear a relationship to the Worcester market. This relationship is seen in a corridor area comprising Hardwick, New Braintree, West Brookfield, and Warren, where wholesale dairymen were about equally divided between the two milksheds.[6] Although producers were so situated in this overlapping area that they could shift from one market to the other, the markets were sufficiently isolated to prevent many shifts even when conditions in the two were radically different. One dealer with a plant in Spencer operated in both markets but was not representative of other dealers as the total business was special milk at special prices. One large Boston dealer with a branch plant in Worcester operated another branch plant in Springfield. One producer-selling cooperative with main offices in Springfield operated a branch plant in Worcester.

These instances constituted all of the direct inter-market relationships in 1935, which, after all, were very few indeed. Worcester is really in the heart of Massachusetts. When one considers that the modern milk industry grew like Topsy with no central guiding organization, it is decidedly interesting that there is so little overlapping among the markets of this area. Overlapping means duplication of services and hence from the beginning it is seen that Worcester has little duplication in the general market setup.

Dealers

In January, 56 regular dealers handled 95 percent of all fluid milk in the market, while 23 producer-dealers and producer-distributors combined handled the remaining 5 percent. Eleven intermediate dealers purchased 2.7 percent of the total supply for resale.

These dealers varied from small producer-distributors selling less than 100 pounds of milk daily, to the market's largest distributor who sold approximately 15,000 pounds daily. Table 1, which contains the distribution by size groups of dealers in the market, shows that the 79 dealers purchased an average of 2,185 pounds of milk daily. The average for 23 producer-dealers and producer-distributors was only 342 pounds daily, compared with 2,942 pounds daily for 56 regular dealers. Of these 56 regulars, 38 were below the average in daily purchases and collectively handled only about a quarter of the total market, while the four largest dealers accounted for a third of the total market. These four dealers were the only distributors in Worcester with daily sales of more than 10,000 pounds each.

Of more significance than distribution of total milk in the market among dealers according to size are the variations among dealers in price plans for paying producers for milk. Previous to the inception of the Massachusetts Milk Control Board, dealers were free to devise their own payment plans, and some small dealers paid on a straight volume basis, allowing no differential for fat content.

From 1917 to 1931 the New England Milk Producers' Association[7] employed a straight use plan of payment for its members in the Boston milkshed.[8] Probably the expansion of that organization from 1922 to 1930 to include in its membership many producers in the Worcester milkshed was the greatest stimulus toward the adoption of the use plan of payment in the Worcester market.

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[6] See figures 1 and 2.

[7] Hereafter called NEMPA.

[8] Schoenfeld, W. A., Some Economic Aspects of the Marketing of Milk and Cream in New England, U. S. D. A., Circular 16, Oct. 1927, p. 54.

Table 1.—Variations in size of business of worcester milk dealers, 1935
(Pounds)

Average Daily Purchases	Dealers		Average Daily Purchases per Dealer	Purchases	
	Number	Percent of Total		Amount	Percent of Total
Less than 1,000	22	27.8	614	4,930,692	7.8
1,000-1,999	10	12.7	1,332	4,862,670	7.7
2,000-2,999	6	7.6	2,415	5,287,777	8.4
3,000-3,999	6	7.6	3,458	7,571,942	12.0
4,000-4,999	3	3.8	4,363	4,777,461	7.6
5,000-9,999	5	6.3	6,492	11,847,966	18.8
Over 10,000	4	5.1	14,288	20,860,873	33.1
Total	56	70.9	2,942	60,139,381	95.4
Producer-Dealers and Producer-Distributors	23	29.1	342	2,871,090	4.6
Grand Totals	79	100.0	2,185	63,010,471	100.0

Since 1931 the use plan of payment has been modified by the base rating[9] system in an effort to even out seasonal variation in production and provide an automatic checking influence on production during the season of excessive surplus. Since its introduction at that time various modifications have ensued. In 1934 when the Massachusetts Milk Control Board became active, it found the base rating plan, the use plan and the straight volume or flat plan all being used. Since September 1934, the Milk Control Board has required all milk-distributing agencies in the Commonwealth to pay producers according to one or another of the three plans, for which details of procedure were established.

In 1935 there were 23 dealers in Worcester buying on the flat plan, 22 buying on the use plan, and 11 employing the base rating plan. Table 2 shows division of the entire market among dealers according to these price plans. Only 12.8 percent of the milk in the market was purchased by the 23 flat-plan dealers compared to 37.8 percent by the 22 use-plan dealers, and 44.8 percent by the 11 rating-plan dealers. The remainder was purchased by producer–dealers and producer–distributors. Table 1 also shows that this last type of dealers was relatively unimportant in the market.

Occasionally dealers performed credit services. In some instances, dealers made regular deduction from producers' milk checks on the accounts of their producers' creditors. In other instances, dealers advanced money to producers on the account of their next milk checks. Dealers frequently have rendered valuable assistance in this manner to producers with poor security.

On the other hand, there were cases of producers performing a banking service for dealers, although the Milk Control Board has set up regulations concerning promptness of dealer payments to producers. In times of stress some dealers have allowed their payments to producers to be in arrears. This, in effect, was a loan to the dealer. To protect producers from loss on such activities by dealers,

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[9] Ibid, pp. 51-57. Also Jensen, Einar, The Boston Milk License, Aug. 1934.

TABLE 2.—DIVISION OF THE WORCESTER MARKET BY PRICE PLANS
Average Daily, 1935

Price Plan	Number of Dealers	Purchases		
		Total Pounds	Percent of Total	Average Pounds per Dealer
Rating	11	77,342	44.8	7,031
Use	22	65,255	37.8	2,966
Flat	23	22,122	12.8	962
Other*	23	7,866	4.6	342
Totals	79	172,585	100.0	2,185

*Producer–Dealers and Producer–Distributors.

the Massachusetts Milk Control Board rigidly enforces dealer bonding regulations, requiring dealers to post bonds representing substantial security.

In addition to can service and various credit services, some of the larger dealers delivered for producers such articles as strainer pads, milk pails, and washing powder. A few dealers sold to producers butter and cheese.

All milk was handled in cans, as there was not sufficient concentration of production in any part of the milkshed to permit economical operation of tank trucks. Most dealers furnished the cans in which milk was transported, charging three-fourths of a cent per hundredweight of milk, the standard rate allowed by the Milk Control Board.

During 1935 one large dealer changed from this plan to producer-owned cans. The dealer sold cans to his producers, receiving payment in three installments deducted from the milk checks of succeeding months, and eliminating the can charge. Since this change, some producers have complained that their cans received unnecessarily rough treatment.

One dealers' association — the Massachusetts Dairies Incorporated — was present in the Worcester market area. This group was organized in 1935 and had some members in the Worcester milkshed who shipped to Boston; therefore, it did not constitute a factor in the market organization of Worcester.

No study has been made of the efficiency of operations of these dealers. Doubtless there was some duplication in the delivery by them to the consumer. There were, however, including the producer–dealers and producer–distributors, who have very few customers, an average of 2400 persons receiving milk from each dealer. If that was the average, then some dealers had a much larger number of customers and there were many with far less. The area of Worcester is large enough so that small dealers would deliver only in certain parts of the city, while the few larger dealers doubtless covered the city rather thoroughly in their routes. There cannot, therefore, be very much overlapping of routes, for all dealers do not have the time to cover the entire city daily. If 79 dealers operate in a market, certainly the consumer has sufficient choice to insure the type of service he prefers; and yet there are not too many dealers, when one considers the number of regular ones, to make this choice cumbersome. Competition should be sufficiently keen to grant the consumers the service they desire.

Sales

There were four kinds of fluid milk sales:

1. Direct retail
2. Wholesale
3. Institutions
4. Other dealers

Many dealers handled all four types of sales while a few specialized in one. Some smaller dealers sold only at retail, while one large dealer sold all of his milk to stores at wholesale. One notable exception to the established channels of milk distribution in Worcester was a grocery store that sold milk, buying directly from a country plant in Vermont.

In this study fluid sales are considered to be the quantities of milk for which dealers paid producers the Class I price. This amount does not always truly represent actual fluid sales for all dealers because of slight discrepancies, but from the dealer's standpoint the quantity purchased at the Class I price is the most important consideration.

The percentage of Class I sales was remarkably high compared with other markets. In November sales were 92 percent of the purchases and the low point was reached in June, when they were 78 percent. The average daily Class I sales were 148,899 pounds, or 86.3 percent of the total purchases. Springfield and Boston, two markets in the same section of the country and hence with rather similar conditions, sold only 75.3 percent and 46.7 per cent respectively of their purchases (Figure 3 and Table 3).

When Class I sales are so large a part of purchases, there is very little surplus in the market. Surplus is one of the chief causes of discontent among the farmers, for it is Class II milk and as such receives a much lower price than Class I. When there is little surplus, the composite price to the farmer is higher; hence, there is not so much dissatisfaction.

Under the Milk Control Board regulations only rating- and use-plan dealers are allowed to pay other than the Class I or fluid prices for any part of their milk supply. For that reason, fluid sales were less than total purchases among only those two types of dealers. For rating-plan dealers, fluid sales represented 88.3 percent of their total purchases, while for use-plan dealers, fluid sales represented 77.5 percent of the milk bought. The flat-plan dealers purchased the same amount of milk that they sold as Class I.

Figure 4 shows the regularity of sales during the year. Fluctuations among dealers by price plan groups was so slight that a constancy of fluid sales was maintained throughout the market. The variation in surplus on the market was due to seasonal production rather than sales. Unfortunately, natural production of milk through the year does not remain so constant as the demand for fluid milk. When the dealers are organized to handle the total production of all their producers, they must find a market for part of the milk at other than fluid use. This amount of surplus was greatest in May for rating-plan dealers, but for use- and flat-plan dealers it was greatest in June, the month of peak production on most farms.

The three grades of milk sold most frequently in Worcester were pasteurized Grade A, pasteurized Grade B, and an intermediate grade of higher fat content. Of 676 full-time producers in the Worcester milkshed, only 22 were Grade A or special milk producers, indicating that Grade A sales were relatively unimportant. The major part of fluid sales was Grade B, but many dealers standardized part of their product at a slightly higher fat test and sold it under some special name at a premium of one cent per quart. Sales of this grade of milk comprised a

TABLE 3. PURCHASES AND SALES IN WORCESTER, SPRINGFIELD AND BOSTON

Average Daily, 1935

Month	Worcester				Springfield				Boston			
	Purchases (Pounds)	Seasonal* Index of Purchases	Sold as Class I		Purchases (Pounds)	Seasonal* Index of Purchases	Sold as Class I		Purchases (Pounds)	Seasonal* Index of Purchases	Sold as Class I	
			Pounds	Percent			Pounds	Percent			Pounds	Percent
January	159,637	92.5	146,533	91.8	210,483	92.4	178,057	84.6	1,373,000	82.1	907,553	66.1
February	164,102	95.1	149,196	90.9	214,417	94.1	177,430	82.7	1,441,000	86.1	894,285	62.1
March	170,792	99.0	147,511	86.4	226,125	99.3	175,048	77.4	1,627,000	97.3	862,635	53.0
April	174,327	101.0	150,600	86.4	235,879	103.5	175,153	74.3	1,826,000	109.2	812,753	44.5
May	187,260	108.5	152,407	81.4	253,538	111.3	174,979	69.0	2,002,000	119.7	789,589	39.4
June	192,176	111.4	151,473	78.8	260,455	114.3	172,200	66.1	2,230,000	133.4	759,538	34.1
July	178,376	103.4	146,835	82.3	235,863	103.5	167,050	70.8	1,959,000	117.2	817,491	41.7
August	174,793	101.3	146,589	83.9	232,014	101.8	165,299	71.2	1,754,000	104.9	808,769	46.1
September	171,987	99.7	146,834	85.4	224,314	98.5	166,269	74.1	1,669,000	99.8	753,554	45.2
October	170,960	99.0	152,208	89.0	223,626	98.2	170,846	76.4	1,546,000	92.5	782,740	50.6
November	160,378	92.9	148,675	92.7	205,579	90.2	171,445	83.4	1,300,000	77.8	801,320	61.6
December	166,237	96.3	148,023	89.0	211,645	92.9	165,284	78.1	1,337,000	80.0	764,497	57.2
Average	172,585	100.0	148,899	86.3	227,828	100.0	171,588	75.3	1,672,000	100.0	780,657	46.7
Range		18.9		13.9		24.1		18.5		55.6		32.0

*1935 Average - 100

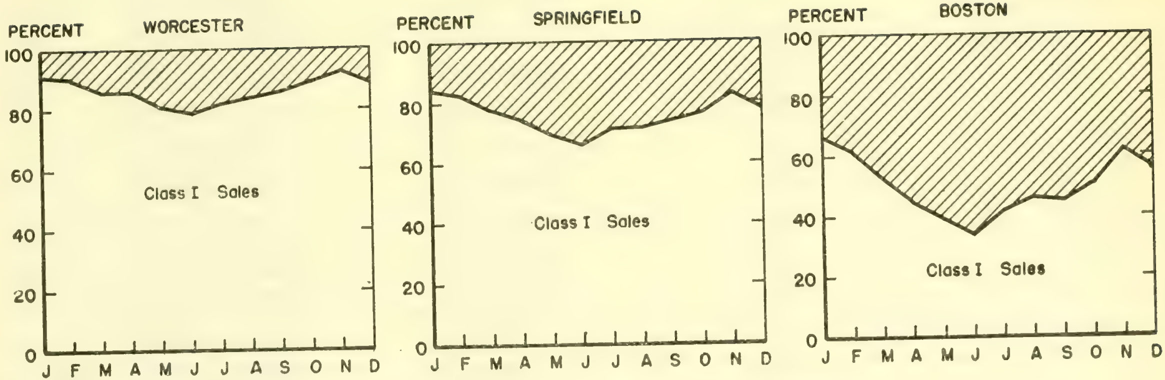


Figure 3. Percentage of Class I Sales in Worcester, Springfield and Boston, 1935.

fairly large proportion of total market sales, although, according to one dealer, the percentage has declined in recent years. In addition to these grades, two dealers sold special grades of milk. Raw milk, if produced under special conditions, was allowed to be sold in Worcester.

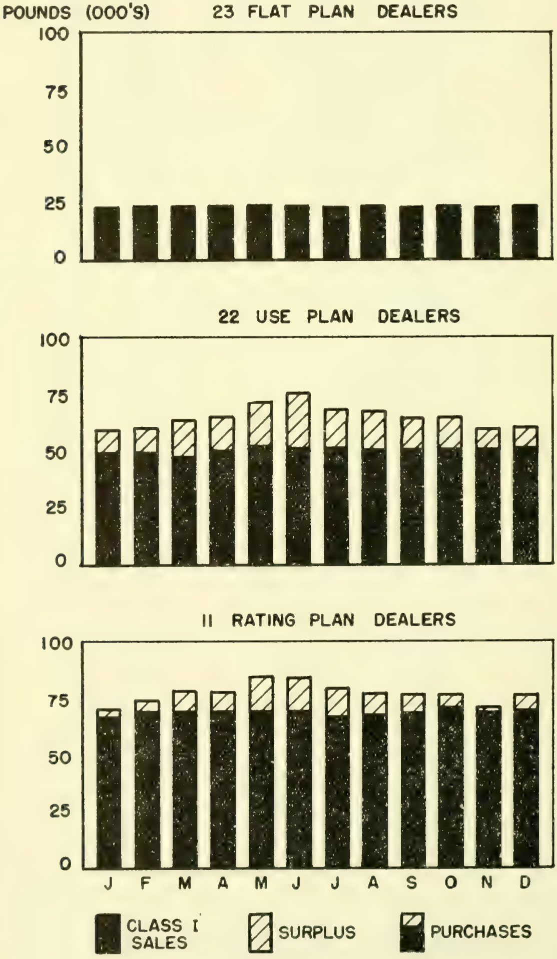


Figure 4. Purchases and Sales according to Price Plan, 1935.

Purchases by Dealers

The supply of milk must be obtained from the farmer originally. A little over 60 million pounds of fluid milk were purchased by the 79 dealers during the year. Information on cream supplies was only available for January and in that month cream dealers purchased an average of 5,759 quarts daily. This amount of cream is the milk equivalent of 123,812 pounds, and the average daily purchases of milk in January were 159,633 pounds.

In January, therefore, Worcester milk dealers purchased daily 283,445 pounds of milk and cream in terms of milk equivalent. For the census population this daily volume indicates a very high per capita consumption of about one and one-half pints, but the actual per capita consumption was probably not so high because of temporary increases in population and because part of the supply was delivered to consumers in neighboring towns.

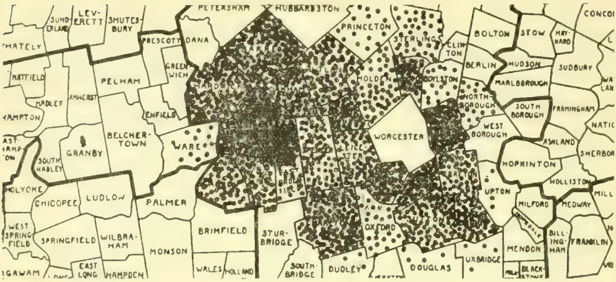
TABLE 4.—WORCESTER CREAM AND MILK SUPPLY BY STATE OF ORIGIN
January, 1935

Cream			Milk		
State of Origin	Quarts	Percent of Total	State of Origin	Pounds	Percent of Total
Michigan	72,000	40.3	Massachusetts	4,543,610	91.8
Vermont	37,200	20.9	Vermont	215,116	4.4
Indiana	32,000	17.9	New York	173,290	3.5
Ohio	24,000	13.4	Connecticut	16,613	.3
Missouri	8,000	4.5			
Connecticut	5,000	2.8	Total Milk	4,948,629	100.0
Maine	320	.2	Total Cream	3,838,180*	
Total	178,520	100.0	Grand Total	8,786,809	

*Milk Equivalent in Pounds.

Table 4 shows the sources of milk and cream supplies in January 1935. Nearly all of the supply of cream was obtained from seven outside states, the largest proportion (40.3 percent) coming from Michigan. Cream per fat unit is much cheaper to transport to market than fluid milk. This enables milk production for cream use in areas of naturally low production costs and accounts for a widely fluctuating creamshed. The dealers' records, however, showed that the sources for the rest of the year were not too different from those in January, varying monthly between Ohio, Indiana, Michigan, and Missouri.

About 92 percent of the fluid milk, on the other hand, was produced in Massachusetts, practically all in Worcester County, and the remaining 8 percent was almost equally divided between Vermont and New York, with a negligible amount coming from Connecticut. Although only 80 percent was produced in Massachusetts in 1930, city milk inspectors serving Worcester for the past several years report that since that year shifts in supply have been comparatively slight. The three maps in Figure 5 bear this out, for they show conclusively that through the years 1930, 1932, and 1935 Worcester's milkshed in Massachusetts varied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SUDBURY
MARLBOROUGH
HADLEY
AMHERST
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OXFORD
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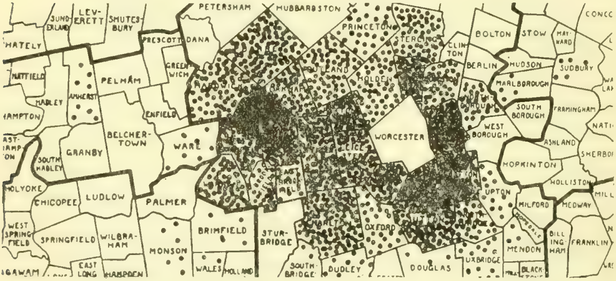
BLACKSTONE

1930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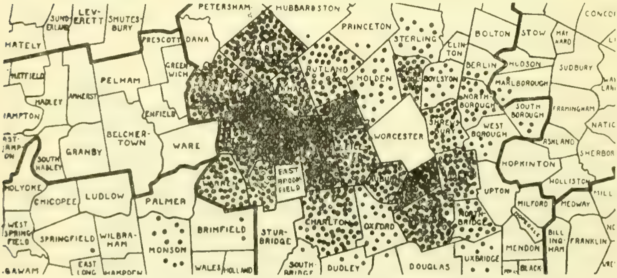
1932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DOUGLAS
UXBRIDGE
BLACKSTONE

1935

• = 100 POUNDS OF MILK

Figure 5. Shipments of Milk to Worcester, 1930, 1932, 1935.

very little. The data for 1930[10] and 1932 consisted of the daily volume shipped in June, while in 1935 the volume was average annual. This difference in averages accounts for the seemingly greater volume of milk shipped in the two earlier years, for June is the month of highest production. On the whole, however, there is very little difference in these three pictures, and it does seem that there was very little shift in the source of milk as far as Massachusetts was concerned during these years.

In this state in 1935 the locations of 107 flat-plan producers, 231 rating-plan producers and 260 use-plan producers were known (Figure 6). The map shows that flat-plan producers predominated northeast of the city and were relatively near to the market. Many use-plan producers were located in the southwest, although west of the city there were about equal numbers of use- and rating-plan producers.

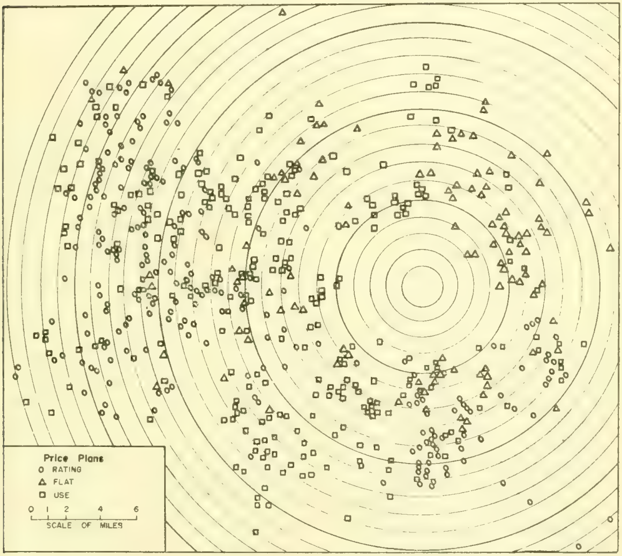

Figure 6. Location of Producers according to Price Plans, 1935.

In 1935 the average daily shipment of milk to Worcester by 676 Massachusetts producers was 194.4 pounds. Table 5 shows that about 30 percent of the farms produced 100 pounds or less daily, 35 percent produced 101-200 pounds, and that the percentage of the farms decreased thereafter as the production increased, although there was a larger number of farms producing over 500 pounds than 401-500 pounds. The number of farms producing 101-200 pounds daily was so large that this class shipped the greatest percentage of milk.

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[10] Lindsey, A. H., op. cit. for 1932 data. The data for 1930 are from unpublished data of the same study.

Table 5.—Division of worcester milk supply among producers by size groups

1935

Average Daily Deliveries (Pounds)	Producers		Deliveries		
	Number	Percent of Total	Total (Pounds)	Percent of Total	Average Daily (Pounds)
0-100	200	29.6	10,879	8.3	54.4
101-200	237	35.1	35,470	27.1	149.7
201-300	102	15.1	24,875	18.9	243.9
301-400	81	12.0	27,771	21.1	342.9
401-500	26	3.8	11,578	8.8	445.3
Over 500	30	4.4	20,821	15.8	694.0
Total	676	100.0	131,394	100.0	194.4

Although there was a decided lack of uniformity in size of production throughout the milkshed, the average daily delivery per farm increased steadily from the center to the outer edge of the shed, and was largest in New Braintree, Hardwick, and Rutland, that area northwest of the city.

Seasonality of milk production varies widely among markets and areas.[11] In order to determine just how much variation existed in Worcester, indices of purchases in the three largest Massachusetts markets were compiled and compared (Table 3 and Figure 7). It is very evident that throughout the year purchases for Worcester varied much less than for the other two markets. It is true, however, that as a market area increases in size there is usually wider seasonal variation in supplies, but it is not known whether or not there is a definite ratio between these two facts. Worcester is the smallest of these areas,[12] and she does exhibit the greatest regularity of purchases; and as there was even more regularity in sales, surplus was necessarily small (Figure 3).

Among dealers in the Worcester market there was some difference in the amount of seasonal variation (Figure 8). Use-plan dealers purchased much more in June than in the lowest months, January and November, but the regularity of purchases by flat-plan dealers helped to level the average curve for Worcester. Dealers of this type went far toward avoiding surplus supplies simply by not buying all the milk produced by their farmers during the months of higher production. Rating-plan purchases were almost the same seasonally as those in the entire market. As about 62 percent of the purchases were fairly regular throughout the year, showing only slight changes seasonally, the Worcester market did not have a surplus problem.

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[11] Gaumnitz, E. W., and Reed, O. M., Some Problems Involved in Establishing Milk Prices, U. S. D. A., A. A. A. Division of Marketing and Marketing Agreements — Dairy Section, Sept. 1937, pp. 48 and 49.

[12] Springfield area includes Holyoke and Chicopee; hence the population of this area according to the 1935 census was approximately 248,000. By the same census the population of metropolitan Boston was 2,064,000 and of Worcester was 190,000.

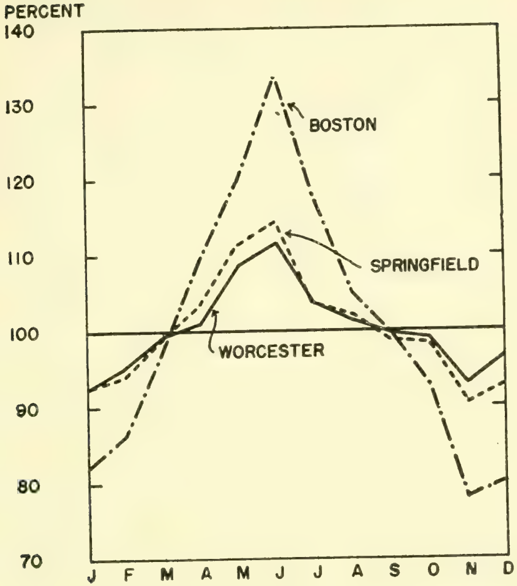

Figure 7. Seasonal Index of Purchases in Worcester, Springfield, and Boston, 1935.

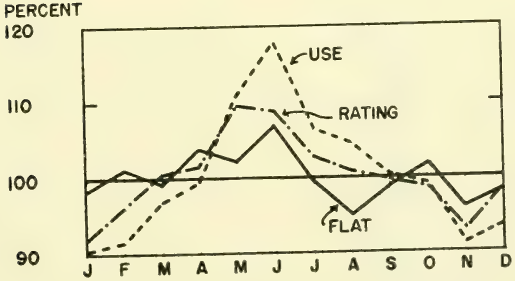

Figure 8. Seasonal Index of Purchases according to Price Plan, 1935.

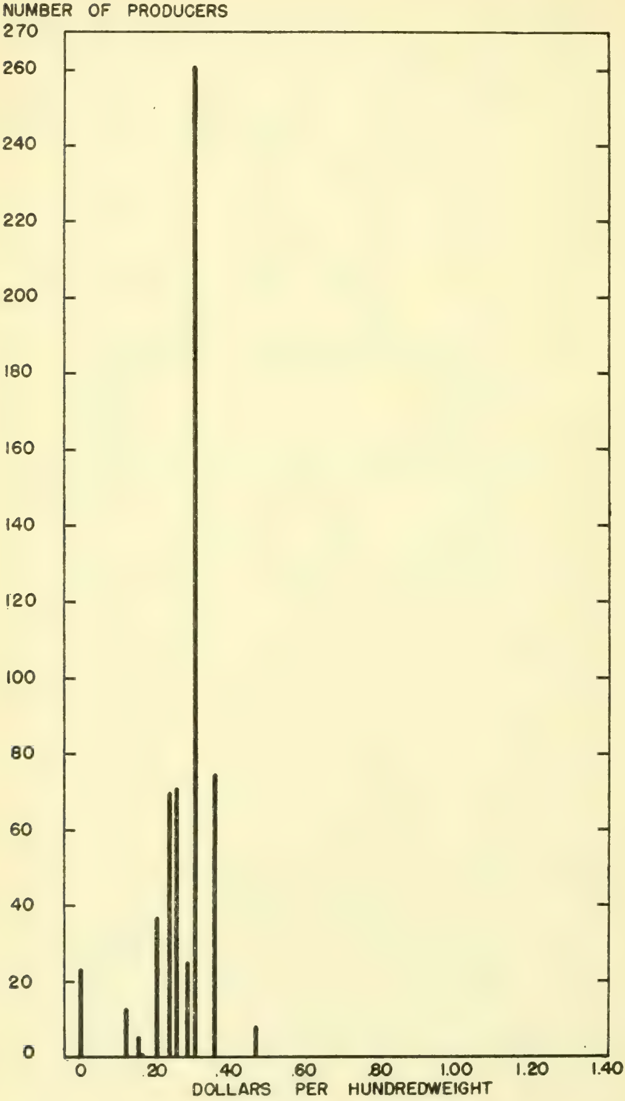

Figure 9. Hauling Charges per Hundredweight to Worcester, 1935.

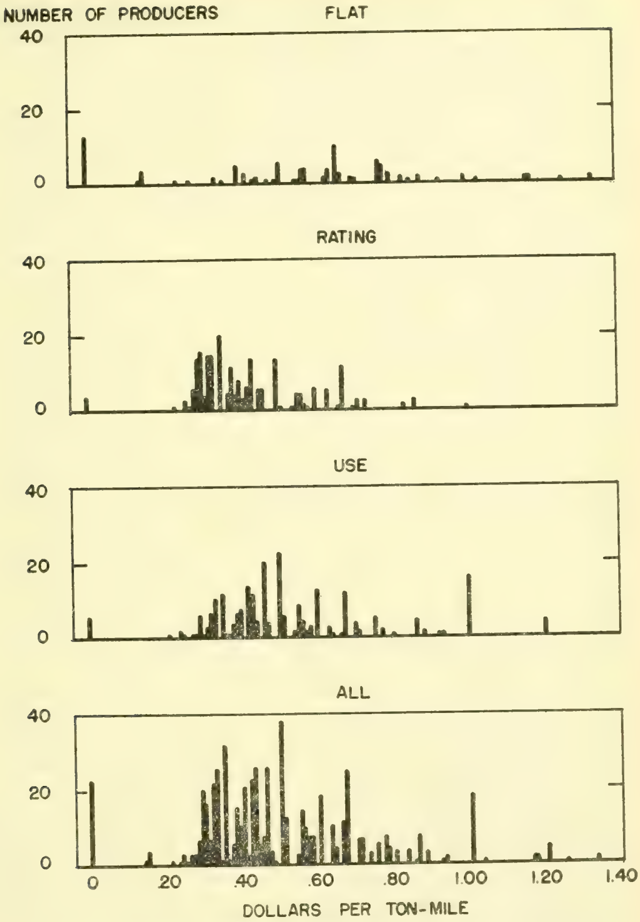

Figure 10. Hauling Charges Paid per Ton-Mile to Worcester according to Price Plans, 1935.

Transportation

All milk produced in Massachusetts and Connecticut for the Worcester market was shipped by truck, while that coming from New York and Vermont arrived via the Boston and Maine Railroad.

Trucking operations were organized in four ways:

1. The largest dealers hired some of their own producers as truckers. These truckmen producers had their business organized to enable them to make one trip to the dealer's plant each morning, hauling milk from a definite route. The common capacity of trucks was two tons and truckers owned their trucks.
2. Many dealers whose receipts could be handled with one truck on one route found that it was advantageous to perform their own trucking operations. Several of them operated their truck routes personally, and were thus enabled to make daily producer-dealer contacts which were not possible for larger dealers.
3. Forty producers, living close to dealers' plants, performed their own trucking operations; thus they avoided the cash hauling charge. Such cases were quite numerous among small dealers with plants located in towns neighboring Worcester. Several producer–dealers with only one or two patrons had them truck their own milk.
4. There were a few instances where the producers of a single dealer were so scattered that their milk was shipped via custom truckers.

The transportation of milk was, therefore, largely in charge of dealers, who set the rates that were deducted from gross payments to producers. Charges for hauling milk from farms in the Massachusetts area of the milkshed to dealers' plants varied from 11.6 to 46.5 cents per hundredweight of milk, or the equivalent of one-fourth to one cent per quart, the extremes representing the charges made by dealers buying on a per quart basis. Between these extremes, 15, 16, 20, 23, 25, 28, 30, and 35 cents per hundredweight of milk were the charges made, although the majority paid 30 cents as seen in Figure 9. In some areas one rate predominated while in other areas a standard rate seemed entirely lacking. The average rate per hundredweight paid by flat-plan producers was the lowest, 22 cents, while the average for the rest was 28 or 29 cents.

In order to judge hauling rates more fairly — i. e. according to mileage hauled — the map showing the location of Massachusetts producers was divided into one-mile zones as shown in Figure 6. It was assumed that the zone in which a farm is located represents the distance of that farm from Worcester. This is not exact because of variations in roads and because some producers do not live on main routes. In other words, the assumed distance from Worcester is almost invariably somewhat less than the actual.

Charges per hundredweight were multiplied by 20 to find the per ton charge, and the result divided by the distance from Worcester assumed as in Figure 6. This amount was the charge per ton-mile and these charges which were paid by Massachusetts producers shipping to Worcester are shown in Figure 10.

When the hauling charges are put in terms of the ton-mile, there is a very wide variation in rates, ranging from 14 cents to $1.33, with the majority from 30 to 68 cents, although 20 of the 598 producers paid $1.00 per ton-mile (most of these 20 were use-plan producers).

When the producers are divided according to the plans by which they were paid, it is evident that the flat-plan producers were the cause of the wide variation. They paid the highest rate generally if rates per ton-mile are considered, and in turn received a higher price for their milk. It is interesting that this group of producers contained 13 of the 40 producers[13] who hauled their own milk, showing that undoubtedly some of the flat-plan producers realized that they were charged a high hauling rate and so trucked their own milk — whether more cheaply or not, it is difficult to say.

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[13] This number includes the 23 producer–dealers and producer–distributors, who, of course, hauled their own milk.

Figures 11 and 12 show the charges per hundredweight and charges per ton-mile by location of the producers who paid these rates. The various charges per hundredweight are very scattered. When, however, the rates are converted by mileage, they show definitely that those producers living nearer the city paid a higher rate for the distance for which their milk was hauled.

The location of a farm with reference to a hard surface or main route and the efficiency of the trucker should be governing factors in fixing hauling charges. In Worcester, though, it would seem that there was a basic charge to cover cost of loading and unloading, and that this charge varied only slightly, and not always in accordance with the distance from the market. Figure 12 shows that the rates did decrease as the distance from market increased. Comparison of these two maps shows also that those producers living between 15 and 21 miles from Worcester paid the same rate, whether by hundredweight or by ton-mile.

Hauling charges for 48 Vermont milk producers shipping to Worcester were available. This milk was first trucked from the farm to a country plant, shipped by rail from the country plant to Worcester, and then hauled by truck from a railroad siding to the dealer's plant. In the country, rates for farm to country plant hauling varied from 10 to 25 cents. Country plant charges were estimated at 19 to 29 cents per hundredweight of milk handled. The freight rate on Vermont milk shipped to Worcester in 1935 was 41.3 cents per hundredweight and it cost five cents per hundredweight to haul the milk from the railroad depot to the dealer's plant.

Comparison of these rates with local hauling rates in the Massachusetts area shows that the cost of transporting Vermont milk to Worcester was from 28.8 to 88.7 cents per hundredweight more than the corresponding cost of Massachusetts milk (Table 6). This differential does not necessarily indicate economy in purchasing Massachusetts milk rather than Vermont milk, but is rather a measure of the comparatively lower cost of production that Vermont producers must have in order to compete in the Worcester market.

TABLE 6.—COSTS OF TRANSPORTING MILK FROM FARMS IN VERMONT AND MASSACHUSETTS TO DEALERS' PLANTS IN WORCESTER, 1935

(Cost per hundredweight)

	Massachusetts		Vermont	
	High	Low	High	Low
Hauling Rate	46.5	11.6	25.0	10.0
Country Plant*			29.0	19.0
Freight			41.3	41.3
City Haul			5.0	5.0
Total	46.5	11.6	100.3	75.3
Less Massachusetts			−11.6	−46.5
Extra Cost for Vermont Milk			88.7	28.8

*Camburn, O. M., *Milk Receiving Station Operation in Vermont*, Vt. Agr. Exp. Sta. Bul. 303, Nov., 1929.

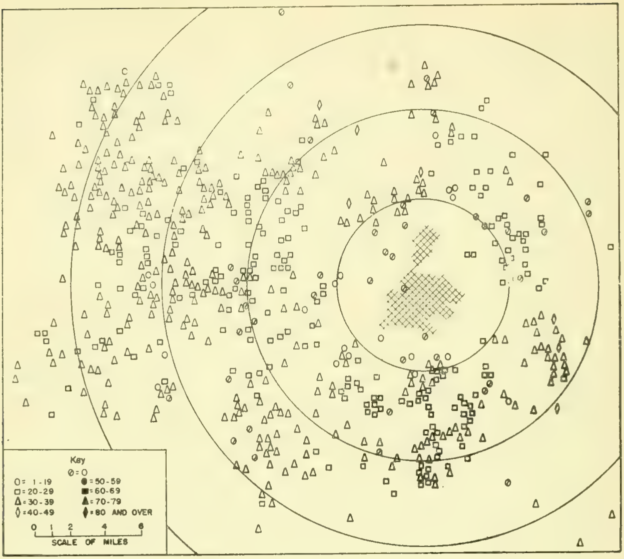

Figure 11. Location of Producers according to Hauling Charges, 1935. (Cents per hundredweight)

There is, to the consumer as well as to anyone else, an appearance of wasted hauling expense in this picture. Why do some pay more to have their milk hauled than others? Why do they not change their methods of shipping their milk to the market? The answer for the producer is that this probably is the very best way to get his milk to market that is available to him. It is apparent that those producers who pay the highest hauling charges on the whole receive the highest prices for their milk. In other words, some dealers try to fool their producers by making them think they are being paid a high price for their milk, when in reality they are obtaining a price similar to that received by the neighboring producers, for the higher price is offset by the higher hauling charge. This difference in rates caused by difference in price explains some of the discrepancies in hauling rates. The rest must be attributed to the fact that milk is a perishable commodity, and as such must reach the market with the greatest speed. Whoever takes that milk to the market for the producer has the producer at his mercy and can just about obtain a monopoly price. There is, however, one limit to this charge. As has been stated previously, the Milk Control Board can rule on excessive hauling charges and has so ruled.

Nothing has been done with respect to routes. A study of certain routes in the Springfield Milkshed has been made[14] and another is in progress. It seems as though a similar study in this market would lead to overlapping of research.

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[14] Brown, A. A., and Donley, J. E., Milk Cartage in the Southwick-Agawam Area of the Springfield Milkshed, Mass. Agr. Exp. Sta., Bul. 363, May 1939.

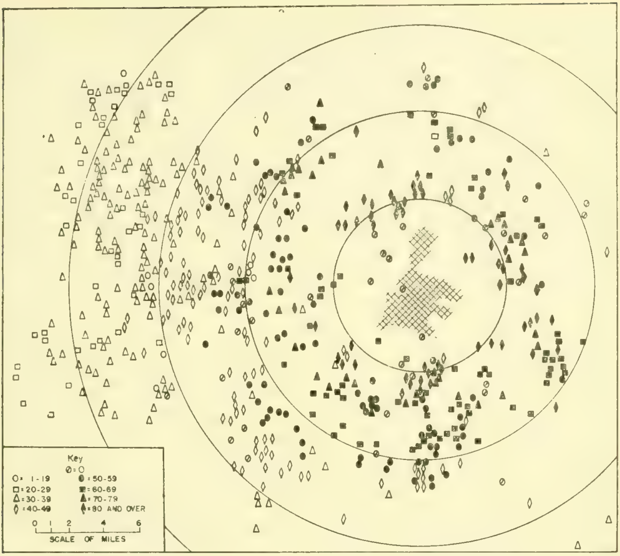

Figure 12. Location of Producers according to Hauling Charges, 1935. (Cents per ton-mile)

Producers

The producers themselves have necessarily been mentioned previously in connection with the various marketing operations. There are, however, a few details concerning them which should not be omitted in a study of this kind.

Part-year producers constituted an average of 9.4 percent of all producers in 1935, the percentage increasing at the rate of 1.1 percent and decreasing at 1.3 percent per month, thus exhibiting no noticeable seasonable fluctuation. Their average daily deliveries, 37 percent less than for full-year producers, were shipped to the market for five and one-half months on the average. These producers were located almost entirely in the section northeast of the city of Worcester — in that area which is highly competitive as far as other markets are concerned.

It was not possible to trace the activities of producers who changed from selling milk to a Worcester dealer to selling to a dealer in another market or vice versa. Such producers were included in the discussion of part-year producers. In addition to such producers already analyzed, 17 full-year producers changed the outlet for their milk from one dealer to another in the market, as did 10 of the part-year producers during their period of activity in the market. All shifts among dealers varied from none in January to six in September. Throughout the year there were about two producers per month who changed from one dealer to another. Worcester was, therefore, rather a stable market as concerned shifts in numbers of producers.

Two producer cooperatives were present in the Worcester market area. One of them, the Worcester division of the United Dairy System, is a combined producing and selling cooperative, the members of which belong to the NEMPA. This last, the NEMPA, with its membership comprising 51.6 percent of all Worcester milk producers in Massachusetts, is a producers' bargaining cooperative that is active also in the Boston market. It is of the price bargaining type, and its sales committee meets with a dealers' sales committee to determine prices. Under government price control, the association cooperates as much as possible with the Milk Control Board and takes the initiative in requesting price advances.

Much of the cream shipped to Worcester from Vermont was purchased through the NEMPA. The intensive dairy regions of Vermont, from which more than 50 percent of the total Boston supply comes, can be considered a potential source of milk for Worcester.

Prices

The average price for Class I milk was $3.281 and for Class II, $1.522 per hundredweight in 1935 (Table 7).

TABLE 7.—BUTTERFAT DIFFERENTIAL AND GROSS PRICE PAID AT DEALERS' PLANTS BY WORCESTER MILK DEALERS, 1935

(Dollars per Hundredweight)

Month	Class I price	Class II price	Butterfat Differential
January	3.0225	1.68	.0453
February	3.0225	1.88	.0507
March 1- 9	3.0225	1.79	.0489
10-31	3.371		
April	3.371	1.85	.0442
May	3.371	1.32	.0358
June	3.371	1.07	.0289
July	3.371	1.22	.0328
August	3.371	1.27	.0343
September	3.371	1.24	.0334
October 1-20	3.371	1.38	.0369
21-31	3.25		
November	3.25	1.78	.0426
December	3.25	1.79	.0485
Average	3.281	1.522	.0410

Net farm prices for milk testing 3.7 per cent butterfat have been used to compare returns for milk among producers in different parts of the milkshed and under different buying plans. Such a price represents a good basis for comparison on a production cost or comparative return basis. It does not show the absolute net return that a price unadjusted for butterfat would show, but a total net price used comparatively would not take into consideration the increased cost of producing milk of higher butterfat content.

In 1935 the average differential allowed in Worcester for milk above or below 3.7 percent butterfat content was 4.1 cents for each one-tenth percent. According to G. F. Dow[15] in a study of producer distribution costs in three areas in Maine, "the cost of producing milk increased about one-fourth cent per quart for each additional increase of 0.3 in the percentages of the butterfat test." This amount equals 3.8 cents per one-tenth percent butterfat compared with the average differential of 4.1 cents actually paid in Worcester in 1935. Although the method of computing costs of producing higher testing milk does not account for seasonal variation, and although producer distributor costs in Maine are only roughly comparable to wholesale-producer costs in Worcester County, Massachusetts, the comparison shows that existent butterfat differentials in the Worcester area are somewhat commensurate with actual production cost differentials.

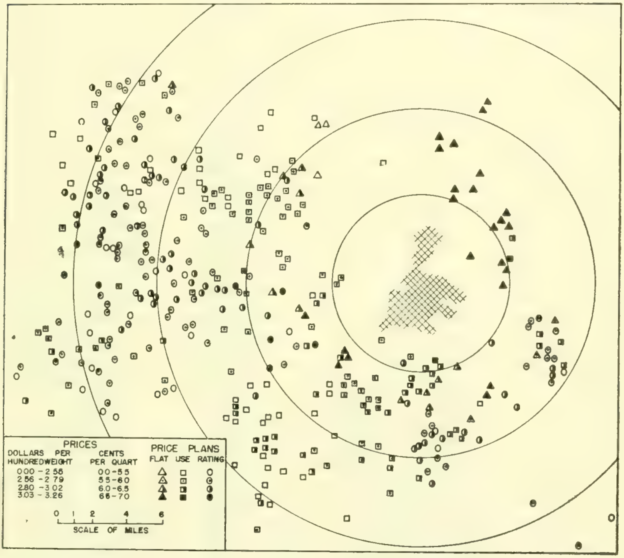

Figure 13. Location of Producers according to Prices Received for Their Milk, 1935.

Net farm prices for 431 producers (71 percent of all full-year producers) were available. Table 8 and Figure 13 show how the group average price decreased from $2.86 in zone 1 to $2.69 in zone 4, although in zone 5 the price was $2.72. This was a decrease of 17 cents per hundredweight in twenty miles, but this did not occur at regular intervals, for over half of the total decrease (11 cents) occurred from zone 2 to zone 3. This same table shows that flat-plan producers received 26 cents per hundredweight more than use-plan, and rating-plan producers 8 cents more than use-plan. Close examination reveals the fact that prices by price plan affect average prices by zones, and vice versa.

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[15] Dow, G. F. An Economic Study of Milk Production Costs in Herds of Producer-Distributors in Maine, Maine Agr. Exp. Sta., Bul. 385, Aug. 1936, p. 48.

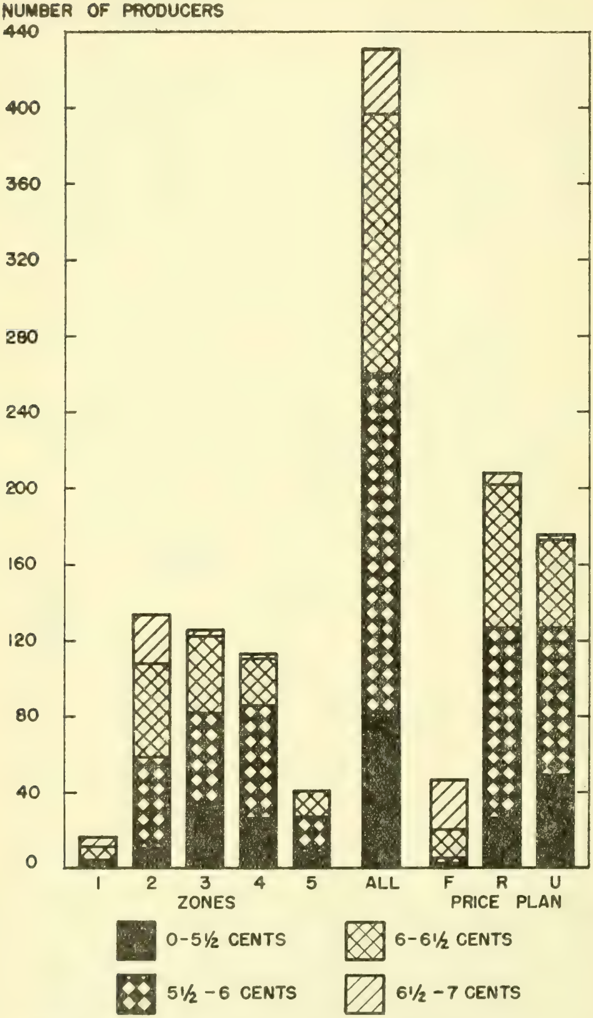

Figure 14. Prices Received by Producers according to Zone and Price Plan. 1935 (Cents per quart)

TABLE 8.—AVERAGE NET PRICES FOR MILK RECEIVED BY USE-, RATING-, AND FLAT-PLAN PRODUCERS IN THE MASSACHUSETTS AREA OF THE WORCESTER MILKSHED BY 5-MILE ZONES, 1935

(Dollars per hundredweight of 3.7 milk)

Price Plan	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Area
Flat	3.01	2.94	2.89	2.97		2.94
Rating	2.77	2.86	2.79	2.70	2.77	2.76
Use	2.81	2.77	2.64	2.60	2.60	2.68
Weighted Average	2.86	2.84	2.73	2.69	2.72	2.75
Rating above use	—.04	.09	.15	.10	.17	.08

Prices per quart which were paid to producers by zones as well as by price plans are illustrated in Figure 14. It is apparent in this chart that the flat-plan producers who received 6½ to 7 cents per quart lived in zone 2; also, that producers receiving this top price lived almost exclusively within ten miles from the center of Worcester. As these prices are net — i. e., the hauling charges have been subtracted as well as other charges — this variation in price is to be expected, although very few farmers receiving the lowest price resided in zone 5.

A multiple correlation coefficient of .5421 was the result of correlating distance from market, hauling charges, and price plans with net 3.7 prices received by producers. As the base price was set by the Milk Control Board, this seemed to be a very small R, although, of course, the variations in Class I and Class II were not taken into consideration. The correlation coefficient of distance and hauling charges was the highest of the small r's, but it was only .4067. Apparently there were some personal factors affecting the hauling charges, as was evident from the previous discussion of hauling charges.

Conclusions

Further study of the channels by which Worcester obtains her milk supply might be made, but it seems as though such study would only prove conclusively that Worcester's supply channels are normal, and for that reason, unusual. In 1935 the amount of surplus hardly warranted mention because it was so small. An equilibrium of supply and demand, practically speaking, had been established. If any part of the channels then existing should be changed, the amount of surplus would doubtless increase.

The transportation phase seems to be the only part which might be more efficiently organized, but that involves personal relationships, and as previously stated, any regulation other than that already in effect by the Massachusetts Milk Control Board would involve curtailment of personal rights by the government and certainly would not be approved by the producers or the dealers. In that case, the consumer could hardly ask for that remedy.

There may be small grumblings, but that is to be expected. There is really nothing radically wrong in the market setup — at least in the supply side of it. The producer sells his milk regularly throughout the year, the dealer has very little surplus to dispose of, and the consumer is assured of a regular supply of good milk throughout the year. It would seem, therefore, that the supply side of the Worcester market was indeed normal.

Appendix

Butterfat differential—A premium or deduction for milk testing above or below 3.7 percent butterfat, expressed as cents per hundredweight of milk for each one-tenth percent of butterfat.

Class I milk—Fluid milk distributed to consumers. Pasteurization is the only change from the natural form allowed for such milk.

Class II milk—Fluid milk purchased from producers supplying Class I milk, but not marketed in fluid form — also called surplus.

Composite price—The average price paid by dealers for all milk purchased. It is an average of the Class I and Class II prices weighted by the proportions of milk sold in the respective classes.

Dealer—An agency purchasing milk for fluid sale from one or more producers, the major activity being selling, not producing.

Flat plan—A method of payment in which the established Class I price is paid for all milk purchased. Such purchase may be on a straight volume basis at the price for milk containing 3.7 percent butterfat, or on a weight and test basis with adjustment above or below 3.7 percent according to an established butterfat differential.

Intermediate dealer—An agency purchasing milk for resale from other dealers rather than from producers.

Primary market—Because of its size, measured by the population of the consuming area, and its relationship to adjoining markets, Boston is the only primary market in Massachusetts.

Producer—One unit, the farmer and his farm, producing milk for sale to dealers or producer-dealers.

Producer-dealer—An agency producing, as well as buying from producers, milk for fluid sale.

Producer-distributor—An agency selling at retail or wholesale delivery milk produced only on his own farm.

Rating plan—A method designed to regulate the supply evenly during the seasons of the year by prorating among the producers the amount of money due to them for milk sold. This is done according to a previously assigned daily average volume, known as the base or rating. Each producer is paid Class I price for milk within his rating and Class II price for that in excess of that rating.

Secondary Market—All organized milk markets in Massachusetts, with the exception of Boston.

Surplus—Class II milk.

Use plan—A method of payment according to the percentage division of a dealer's sales between Class I and Class II milk. Such percentage division is periodically applied equally to all producers of a single dealer.

Worcester area—Sales area number 8 as determined by the Massachusetts Milk Control Board. The towns of Rutland, Holden, West Boylston, Boylston, Paxton, Worcester, Shrewsbury, Spencer, Leicester, Auburn, Millbury, and Grafton are included.

Worcester market—The area served by milk distributors licensed by the city of Worcester to sell milk. This includes the city business, that in adjoining towns of dealers located in the city, as well as that of distributors located in nearby towns with sales in Worcester. In the case of distributors who are located in towns outside of the general sales area but operate in the city, only Worcester sales are included.

Worcester milkshed—The geographic area in which producers for the Worcester market are located.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 367 December 1939

Meteorological Records

A Fifty-Year Summary

1889-1938

By C. I. GUNNESS

OBSERVATORY

Latitude 42° 23′ 48.5″ N. Longitude 72° 31′ 10″ W.

Height of barometer above ground, 36 ft.; above sea level, 262.3 ft.

Height of wind instruments, 67 ft. Time used, 75th Mer.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

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METEOROLOGICAL RECORDS

A FIFTY-YEAR SUMMARY, 1889 - 1938

By C. I. GUNNESS, Professor of Engineering

Location and Equipment

The meteorology observatory is located on the third floor of Stockbridge Hall. It was moved to this location from South College on June 12, 1928, where it had been located since 1889. The records up to June 12, 1928, therefore, were taken at the old location; since June 12, 1928, they have been taken at the new location.

In the old location the observatory was in the tower of South College, about 50 feet above the ground. The base of the tower is 237 feet above sea level and the top of the tower is 72 feet above the ground. The exposure is good in all directions. The anemometer, wind vane, and sunshine recorder were mounted from 3 to 5 feet above the tower, with the recording apparatus in the room below. The thermometer shelter and rain gauges were on the campus about 300 feet southwest from the tower and on slightly lower ground. The rain gauges were about 2 feet above ground and 232 feet above sea level.

In the present location the anemometer, wind vane, and sunshine recorder are located from 4 to 7 feet above the roof of Stockbridge Hall. The roof is 60 feet above the ground with good exposure. The thermometer shelter and rain gauges are about 300 feet west from Stockbridge Hall.

The same equipment is used in the new location as was used in the old, except as noted below. The standard barometer is of United States Weather Bureau pattern. A Draper mercury-column type recording barometer and a Friez electrical sunshine recorder are used. A four-cup anemometer was used until January 1, 1930, when a three-cup anemometer was installed. The records of sunshine, wind velocity, and rainfall are recorded on a triple register. A United States Weather Bureau gauge is used in determining precipitation; and a tipping-bucket electrical-recording gauge, in determining the time and rate. The latter gauge is now located on the roof of the Engineering building, and serves to measure melted snow as well as rain. The wind direction is recorded on a Draper anemoscope. A Friez hygro-thermograph was installed in April 1929, in place of the Draper recording thermometer used until that time.

On January 1, 1904, the time of making observations was changed from 7 a.m., 2 p.m. and 9 p.m. to 8 a.m. and 8 p.m., so as to conform with the practice of the United States Weather Bureau. This change should be noted in comparing the dew point and relative humidity before and after that date. Other data are probably not affected by the change.

MEAN BAROMETER

[Readings are reduced to freezing and sea level]

YEAR	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889	30.11	30.24	29.84	29.80	29.92	29.96	29.91	30.01	30.00	30.05	30.04	30.14	30.00
1890	30.19	30.10	29.99	30.10	29.96	29.98	30.02	30.00	30.12	29.88	30.01	30.01	30.03
1891	29.96	30.04	30.10	29.92	29.98	29.92	29.99	29.96	30.11	30.03	30.12	30.08	30.02
1892	29.96	30.11	29.90	29.97	29.94	29.92	29.99	30.02	30.10	29.90	29.99	30.01	29.98
1893	29.95	30.11	30.06	30.09	29.90	30.06	29.97	30.00	30.06	30.13	30.12	30.12	30.05
1894	30.18	30.16	30.09	30.05	30.00	30.00	30.01	30.03	30.14	30.02	30.08	30.15	30.08
1895	30.05	29.92	30.00	30.12	30.10	30.17	30.03	30.02	30.10	30.08	30.19	30.15	30.08
1896	30.16	29.86	29.99	30.14	29.98	29.95	29.97	29.99	30.00	30.01	30.14	30.14	30.03
1897	30.04	30.06	30.04	30.04	29.92	29.90	29.94	29.94	30.09	30.12	30.03	30.04	30.01
1898	29.98	30.05	30.20	29.93	29.94	29.95	30.02	29.96	30.01	30.09	30.01	29.96	30.01
1899	30.11	29.98	29.94	30.04	30.00	29.98	29.93	29.98	30.02	30.19	30.01	30.03	30.02
1900	30.03	29.97	29.95	29.96	29.91	29.91	29.91	29.99	30.04	30.15	29.99	30.03	29.98
1901	29.95	29.79	29.90	29.97	29.88	29.95	29.93	30.02	30.03	30.08	29.93	30.03	29.96
1902	30.04	29.78	29.91	29.88	29.84	29.84	29.96	29.92	30.04	30.03	30.06	30.06	29.95
1903	29.91	29.98	30.20	29.87	29.94	29.94	29.88	30.00	30.10	30.00	30.01	29.97	30.00
1904	30.08	30.11	30.11	29.97	30.02	30.02	29.98	30.03	30.08	30.08	29.95	30.02	30.03
1905	30.08	30.12	30.12	29.85	29.93	29.93	29.95	29.98	30.05	30.10	30.01	30.08	29.94
1906	30.09	30.20	30.09	29.98	29.94	29.94	29.98	30.02	30.09	30.09	30.04	30.12	30.05
1907	30.23	30.09	30.08	29.88	29.93	29.93	29.87	30.00	30.02	30.05	30.05	30.02	30.02
1908	29.97	30.08	30.10	29.92	30.03	30.03	30.04	30.03	30.10	30.17	30.01	30.04	30.04
1909	30.15	29.96	29.82	30.06	29.94	29.97	29.91	30.02	30.11	30.03	30.16	29.89	30.01
1910	30.11	30.07	30.08	29.97	29.96	29.92	29.89	30.07	30.10	30.01	29.80	30.03	30.00
1911	30.12	30.12	29.99	30.14	30.03	29.94	29.99	30.02	30.06	30.11	30.01	30.15	30.06
1912	30.02	29.93	30.13	29.99	29.96	29.99	29.98	29.95	30.07	30.06	30.00	30.01	30.01
1913	30.10	30.01	30.11	30.02	29.99	30.00	29.94	30.03	30.13	29.97	30.13	30.01	30.04
1914	29.96	30.13	30.00	30.03	30.04	29.95	29.98	30.01	30.13	30.10	30.07	30.18	30.05
1915	30.12	30.12	29.83	30.03	29.91	30.02	29.92	29.98	30.05	30.08	29.99	29.95	29.99
1916	30.18	30.01	29.96	29.92	29.91	29.95	29.98	29.98	30.04	30.13	30.10	29.93	30.01
1917	30.01	29.93	30.06	29.93	29.81	30.00	29.95	30.01	30.11	30.05	30.07	30.22	30.01
1918	29.88	30.06	29.99	30.07	30.06	29.92	29.97	30.03	30.03	30.12	30.02	30.13	30.02
1919	30.01	29.96	30.12	30.03	29.98	30.13	29.97	29.94	30.02	30.12	30.08	30.11	30.03
1920	30.17	29.98	29.97	29.82	30.06	29.95	29.96	30.06	29.99	30.07	30.13	29.96	30.00
1921	30.11	30.08	30.15	30.06	30.01	29.94	29.98	30.07	30.03	29.97	30.08	30.01	30.04
1922	30.18	30.12	30.10	30.04	30.02	29.96	30.02	29.99	30.11	29.99	30.02	30.15	30.06
1923	30.08	30.12	30.02	29.96	29.95	29.85	30.00	29.96	30.11	30.10	30.07	30.04	30.02
1924	30.14	30.07	29.77	29.95	29.85	29.93	29.95	29.97	30.09	30.21	30.06	30.13	30.01
1925	30.20	30.06	30.07	30.03	29.94	29.96	29.92	30.06	30.05	29.98	30.09	29.90	30.02
1926	29.99	29.87	29.93	29.93	29.88	29.92	29.96	30.00	30.14	29.94	30.11	30.10	29.98
1927	30.13	30.04	30.10	30.06	29.92	29.98	29.97	30.00	30.02	29.97	30.09	30.04	30.03
1928	29.96	30.07	29.88	29.98	29.92	29.91	29.95	30.03	30.06	30.11	30.00	30.10	30.00
1929	30.02	29.93	29.92	29.92	30.05	29.91	30.00	29.97	30.11	30.06	30.04	30.05	29.94
1930	30.23	30.07	29.76	30.04	29.94	29.93	29.89	29.95	29.98	30.06	30.18	29.71	29.98
1931	29.97	30.02	29.90	30.01	29.93	29.94	29.91	29.99	29.99	30.02	29.81	30.06	29.96
1932	30.12	30.00	29.74	29.92	30.02	29.89	29.83	30.00	30.06	30.03	30.21	30.19	30.00
1933	30.01	29.95	29.92	30.00	29.94	29.91	29.99	30.01	29.93	30.11	29.97	30.10	29.99
1934	30.08	30.12	30.14	30.00	29.98	29.90	29.95	30.03	30.13	30.03	30.13	30.05	30.04
1935	30.01	30.05	30.06	29.90	29.95	29.95	30.00	30.01	30.05	30.18	30.12	30.00	30.02
1936	29.96	30.09	29.94	30.01	30.00	29.86	29.87	30.01	30.10	30.09	30.03	30.27	30.02
1937	30.25	29.97	29.87	30.02	29.95	29.91	29.96	30.07	30.07	30.05	30.06	30.10	30.02
1938	30.07	30.16	30.01	30.05	29.94	29.99	29.98	29.99	30.04	30.12	30.17	30.05	30.05
Mean . . .	30.07	30.04	30.00	29.99	29.96	29.95	29.96	30.00	30.06	30.06	30.05	30.06	30.01

Range of Barometer (in Inches)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889	1.62	1.51	1.58	1.16	.75	.97	.68	.66	.98	.96	1.31	1.75	1.81
1890	1.50	1.35	1.08	1.08	.81	.58	.63	1.10	.69	1.09	.98	1.20	1.76
1891	1.93	1.36	1.21	1.42	.79	.53	.74	.61	.73	1.11	1.56	1.22	2.05
1892	1.38	1.65	1.16	1.02	.96	.84	.97	.55	.96	.98	1.00	1.01	1.65
1893	1.53	1.83	1.27	1.25	1.16	.67	.68	.93	.81	1.37	1.16	1.53	1.92
1894	1.89	1.65	1.04	.86	.93	.75	.57	.44	1.11	1.19	1.22	1.23	2.01
1895	1.46	1.88	1.24	1.40	.84	.66	.51	.53	.68	1.09	1.47	1.78	2.27
1896	.97	1.77	1.52	.96	.75	.83	.79	.59	.85	1.10	1.23	1.57	2.22
1897	1.57	1.15	1.74	1.10	.76	.55	.72	.61	.73	1.12	1.48	1.42	1.76
1898	1.43	1.63	1.17	.86	.76	.95	.81	.60	.82	1.19	1.25	1.39	1.75
1899	1.70	1.41	1.54	.90	.60	.59	.51	.56	.88	.76	1.10	1.58	1.82
1900	1.58	1.89	1.52	1.01	.99	.67	.73	.53	1.03	1.07	1.71	1.53	1.89
1901	1.68	.97	1.17	1.19	.77	.61	.59	.51	1.00	1.22	1.14	1.13	1.68
1902	1.49	1.41	1.55	1.04	.94	1.27	.58	.67	.78	1.25	1.12	1.34	1.89
1903	1.49	1.55	1.19	1.15	.85	.97	.57	.77	.78	1.08	1.32	1.56	1.77
1904	1.50	1.36	1.58	1.00	.75	.81	.73	.73	1.20	1.23	1.84	1.43	2.23
1905	1.37	1.28	.89	1.15	.85	.83	.58	.72	.66	1.16	1.22	1.53	1.64
1906	1.53	1.28	1.64	1.05	1.08	.77	.90	.72	1.03	1.41	1.05	1.30	1.70
1907	1.34	1.27	1.39	1.42	.67	.71	.76	.71	.91	1.24	1.59	1.46	1.79
1908	1.73	1.89	1.22	1.35	1.11	.65	.66	.68	.73	1.17	1.14	1.31	1.97
1909	1.64	1.63	1.52	1.14	.82	.68	.88	.97	.80	.97	1.24	1.54	1.91
1910	1.76	1.40	1.11	.90	1.02	.83	.57	.82	.57	1.05	1.02	1.44	1.76
1911	1.50	1.09	1.77	1.14	.97	.69	.74	.76	.85	1.04	1.24	1.20	1.77
1912	1.60	1.75	1.43	1.32	.86	.64	.89	.77	.75	.87	1.17	1.46	1.98
1913	2.18	.88	1.92	1.06	.87	.80	.65	.72	.83	1.38	1.65	1.34	2.33
1914	1.45	1.50	2.10	1.06	1.01	.65	.55	.55	.84	1.00	1.32	1.52	2.31
1915	1.26	1.31	.85	.99	.83	.64	.74	.59	1.03	.83	1.29	1.67	1.73
1916	1.17	1.84	1.25	.94	1.10	.52	.84	.76	.87	1.03	1.53	1.51	1.88
1917	1.38	1.50	1.09	1.09	.80	.58	.56	.70	1.05	1.11	1.08	1.66	1.93
1918	1.70	1.82	1.01	.96	.99	.93	.53	.76	.73	1.01	1.55	1.19	1.86
1919	1.35	1.16	1.72	.72	.70	.73	.78	.64	.83	1.06	1.16	1.26	1.72
1920	1.58	1.84	1.52	.94	.73	.78	.72	.78	1.02	1.13	1.27	1.25	2.02
1921	1.50	1.09	1.01	1.05	.72	.75	.56	.74	.79	1.15	1.02	1.43	1.57
1922	1.78	1.25	1.31	1.05	.95	.81	.56	.70	.79	.99	1.03	1.02	1.78
1923	1.41	1.10	1.63	1.27	.85	.87	.73	.72	.71	.84	1.28	1.51	1.55
1924	1.44	1.13	.98	.98	.98	.78	.72	.73	1.10	.90	1.38	1.40	1.58
1925	1.57	1.22	1.22	.96	.89	.74	.52	.70	.95	1.43	1.59	1.11	1.68
1926	1.22	1.20	1.41	.99	.98	.70	.83	.65	.62	1.47	1.21	1.12	1.62
1927	1.70	1.06	1.09	1.00	.94	.69	.57	.66	.95	1.24	1.71	1.64	1.98
1928	1.71	1.40	1.28	1.09	.88	.65	.57	.68	.70	1.00	1.10	1.41	1.83
1929	1.61	.89	1.41	1.40	1.21	.67	.84	.84	.87	1.35	1.36	1.30	1.75
1930	1.03	.98	1.43	1.52	.77	.90	.65	1.49	.69	1.00	1.71	1.26	1.91
1931	1.52	.88	1.18	1.21	.66	.76	.70	1.00	.91	1.15	1.07	1.08	1.73
1932	1.24	1.06	1.68	1.23	.70	.84	.81	.60	1.09	1.00	1.50	1.34	2.23
1933	1.33	1.34	1.38	1.14	.73	.55	.74	.82	.88	1.11	1.36	1.38	1.38
1934	1.65	1.72	1.21	1.39	1.04	.82	.69	.79	.78	1.02	1.33	1.44	1.79
1935	1.40	1.29	1.23	.93	.86	.74	.73	.74	.88	1.02	.94	1.24	1.46
1936	1.37	1.07	1.35	1.11	1.11	.86	.76	.65	.90	1.44	1.33	1.41	1.69
1937	1.30	1.14	1.08	1.04	.70	.84	.61	.57	1.03	1.33	1.22	1.42	1.69
1938	1.19	1.63	1.10	1.40	1.33	.76	.47	.57	1.99	.96	1.08	1.37	2.47
Mean	1.51	1.38	1.34	1.11	.88	.75	.68	.71	.88	1.11	1.29	1.38	1.85

MAXIMUM BAROMETER

YEAR	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889	30.82	30.97	30.66	30.54	30.40	30.54	30.35	30.45	30.40	30.52	30.67	30.96	30.97
1890	30.94	30.72	30.56	30.57	30.32	30.28	30.27	30.28	30.42	30.41	30.35	30.61	30.94
1891	30.62	30.69	30.57	30.56	30.44	30.22	30.37	30.27	30.45	30.67	30.74	30.55	30.74
1892	30.67	30.72	30.45	30.53	30.43	30.39	30.50	30.24	30.42	30.43	30.44	30.53	30.72
1893	30.61	30.83	30.63	30.65	30.32	30.36	30.25	30.30	30.45	30.65	30.70	30.92	30.92
1894	30.77	30.89	30.57	30.52	30.50	30.33	30.31	30.24	30.63	30.42	30.73	30.53	30.89
1895	30.61	30.44	30.52	30.70	30.55	30.51	30.33	30.29	30.41	30.67	30.73	30.83	30.83
1896	30.56	30.49	30.62	30.60	30.48	30.42	30.49	30.39	30.40	30.62	30.86	30.94	30.94
1897	30.77	30.70	30.88	30.61	30.36	30.28	30.33	30.18	30.40	30.67	30.60	30.60	30.88
1898	30.61	30.64	30.76	30.34	30.33	30.35	30.44	30.26	30.41	30.46	30.53	30.52	30.76
1899	30.92	30.53	30.49	30.39	30.29	30.25	30.24	30.31	30.47	30.50	30.54	30.66	30.92
1900	30.67	30.75	30.59	30.48	30.38	30.19	30.16	30.25	30.35	30.52	30.64	30.51	30.75
1901	30.69	30.34	30.43	30.52	30.20	30.24	30.29	30.28	30.51	30.66	30.37	30.58	30.69
1902	30.66	30.27	30.50	30.28	30.43	30.46	30.29	30.26	30.38	30.52	30.48	30.75	30.75
1903	30.62	30.48	30.65	30.46	30.54	30.39	30.17	30.42	30.42	30.40	30.70	30.60	30.70
1904	30.90	30.67	30.96	30.50	30.37	30.35	30.26	30.42	30.62	30.57	30.57	30.54	30.96
1905	30.70	30.62	30.60	30.37	30.38	30.19	30.15	30.27	30.41	30.58	30.63	30.86	30.86
1906	30.78	30.95	30.92	30.45	30.49	30.35	30.46	30.38	30.50	30.63	30.42	30.77	30.95
1907	30.75	30.78	30.59	30.41	30.34	30.22	30.18	30.35	30.39	30.60	30.59	30.45	30.78
1908	30.59	30.83	30.59	30.52	30.31	30.40	30.26	30.34	30.45	30.59	30.45	30.61	30.83
1909	30.75	30.53	30.36	30.60	30.29	30.26	30.27	30.39	30.52	30.52	30.74	30.58	30.75
1910	30.87	30.80	30.50	30.40	30.40	30.24	30.18	30.37	30.34	30.47	30.40	30.78	30.87
1911	30.66	30.64	30.72	30.71	30.40	30.24	30.26	30.30	30.41	30.59	30.48	30.57	30.72
1912	30.59	30.47	30.70	30.62	30.31	30.31	30.35	30.29	30.37	30.46	30.50	30.61	30.70
1913	30.73	30.44	30.88	30.56	30.39	30.43	30.19	30.41	30.58	30.52	30.72	30.47	30.88
1914	30.53	30.68	30.57	30.43	30.50	30.29	30.21	30.26	30.53	30.60	30.78	30.69	30.78
1915	30.56	30.58	30.37	30.51	30.28	30.23	30.22	30.28	30.37	30.41	30.48	30.52	30.58
1916	30.64	30.60	30.44	30.27	30.32	30.13	30.35	30.27	30.53	30.53	30.55	30.47	30.64
1917	30.74	30.43	30.53	30.33	30.27	30.33	30.22	30.29	30.54	30.40	30.54	30.86	30.86
1918	30.54	30.70	30.46	30.55	30.50	30.24	30.22	30.48	30.42	30.57	30.60	30.70	30.70
1919	30.68	30.43	30.92	30.37	30.44	30.51	30.37	30.28	30.39	30.61	30.53	30.67	30.92
1920	30.99	31.05	30.55	30.14	30.45	30.32	30.24	30.40	30.37	30.39	30.62	30.60	31.05
1921	30.90	30.52	30.65	30.56	30.42	30.27	30.21	30.35	30.33	30.48	30.52	30.79	30.90
1922	30.70	30.60	30.63	30.43	30.48	30.21	30.23	30.33	30.46	30.49	30.39	30.69	30.70
1923	30.84	30.66	30.78	30.61	30.29	30.19	30.40	30.20	30.45	30.42	30.62	30.81	30.84
1924	30.77	30.75	30.21	30.41	30.24	30.34	30.23	30.28	30.65	30.60	30.58	30.59	30.77
1925	30.76	30.44	30.64	30.53	30.34	30.32	30.16	30.42	30.59	30.53	30.67	30.47	30.76
1926	30.53	30.40	30.60	30.34	30.36	30.29	30.33	30.40	30.41	30.47	30.55	30.62	30.62
1927	31.00	30.45	30.49	30.46	30.47	30.30	30.30	30.36	30.44	30.37	30.73	30.76	31.00
1928	30.61	30.73	30.48	30.47	30.38	30.13	30.24	30.34	30.38	30.55	30.53	30.53	30.73
1929	30.74	30.48	30.42	30.39	30.54	30.16	30.41	30.30	30.61	30.68	30.51	30.72	30.74
1930	30.77	30.60	30.43	30.59	30.34	30.33	30.16	30.36	30.33	30.40	30.78	30.64	30.78
1931	30.48	30.51	30.40	30.51	30.21	30.27	30.13	30.37	30.48	30.43	30.69	30.63	30.69
1932	30.61	30.54	30.32	30.40	30.43	30.29	30.08	30.31	30.49	30.53	30.87	30.68	30.87
1933	30.69	30.65	30.37	30.49	30.24	30.17	30.31	30.35	30.31	30.65	30.47	30.87	30.87
1934	30.69	30.83	30.68	30.63	30.52	30.39	30.40	30.50	30.53	30.53	30.75	30.50	30.83
1935	30.81	30.78	30.71	30.28	30.37	30.22	30.34	30.31	30.37	30.61	30.49	30.68	30.81
1936	30.54	30.47	30.43	30.51	30.62	30.29	30.23	30.33	30.49	30.61	30.67	30.77	30.77
1937	30.85	30.39	30.37	30.53	30.36	30.32	30.18	30.32	30.55	30.67	30.58	30.58	30.85
1938	30.40	30.88	30.45	30.50	30.43	30.41	30.17	30.19	30.40	30.49	30.64	30.67	30.88
Mean . . .	30.70	30.63	30.57	30.48	30.39	30.30	30.27	30.32	30.45	30.53	30.59	30.66	30.81
Maximum .	31.00	31.05	30.96	30.71	30.62	30.54	30.50	30.50	30.65	30.68	30.87	30.96	31.05

MINIMUM BAROMETER

YEAR	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889	29.20	29.46	29.08	29.38	29.65	29.57	29.67	29.79	29.42	29.56	29.36	29.21	29.08
1890	29.44	29.37	29.48	29.49	29.51	29.70	29.64	29.18	29.73	29.32	29.37	29.41	29.18
1891	28.69	29.33	29.36	29.14	29.65	29.69	29.63	29.66	29.72	29.56	29.18	29.33	28.69
1892	29.29	29.07	29.29	29.51	29.47	29.55	29.53	29.69	29.46	29.45	29.44	29.52	29.07
1893	29.08	29.00	29.36	29.40	29.16	29.69	29.57	29.37	29.64	29.28	29.54	29.39	29.00
1894	28.88	29.24	29.53	29.66	29.57	29.58	29.74	29.80	29.52	29.23	29.51	29.30	28.88
1895	29.17	28.56	29.28	29.30	29.71	29.85	29.82	29.76	29.73	29.58	29.26	29.05	28.56
1896	29.59	28.72	29.10	29.64	29.73	29.59	29.70	29.80	29.55	29.52	29.63	29.37	28.72
1897	29.20	29.55	29.14	29.51	29.60	29.63	29.61	29.57	29.67	29.55	29.12	29.18	29.12
1898	29.18	29.01	29.59	29.48	29.57	29.40	29.63	29.66	29.59	29.27	29.28	29.13	29.01
1899	29.22	29.12	28.95	29.49	29.69	29.66	29.63	29.75	29.56	29.74	29.44	29.10	29.10
1900	29.08	28.86	29.06	29.47	29.39	29.51	29.42	29.72	29.32	29.42	28.93	28.98	28.86
1901	29.01	29.37	29.26	29.33	29.43	29.63	29.70	29.76	29.51	29.44	29.23	29.42	29.01
1902	29.17	28.86	28.95	29.24	29.49	29.24	29.61	29.59	29.60	29.27	29.36	29.41	28.86
1903	29.13	28.93	29.46	29.31	29.69	29.42	29.60	29.65	29.69	29.32	29.38	29.04	28.93
1904	29.40	29.31	29.38	29.50	29.62	29.54	29.53	29.69	29.42	29.28	28.73	29.11	28.73
1905	29.33	29.34	29.71	29.22	29.53	29.36	29.57	29.55	29.75	29.42	29.41	29.33	29.22
1906	29.25	29.67	29.28	29.40	29.41	29.58	29.56	29.66	29.47	29.22	29.37	29.47	29.25
1907	29.41	29.51	29.29	28.99	29.69	29.51	29.42	29.64	29.48	29.36	29.00	29.05	28.99
1908	28.86	28.94	29.37	29.27	29.20	29.75	29.69	29.66	29.72	29.42	29.31	29.30	28.86
1909	29.11	28.90	28.84	29.46	29.47	29.58	29.39	29.42	29.72	29.55	29.50	29.04	28.84
1910	29.11	29.40	29.39	29.50	29.38	29.41	29.61	29.55	29.77	29.42	29.38	29.34	29.11
1911	29.16	29.55	28.95	29.57	29.43	29.55	29.52	29.54	29.56	29.55	29.24	29.37	28.95
1912	28.99	28.72	29.27	29.30	29.45	29.67	29.46	29.52	29.62	29.59	29.33	29.15	28.72
1913	28.55	29.56	29.26	29.50	29.52	29.63	29.54	29.69	29.75	29.14	29.07	29.13	28.55
1914	29.08	29.18	28.47	29.37	29.49	29.64	29.66	29.71	29.69	29.60	29.46	29.17	28.47
1915	29.30	29.27	29.52	29.52	29.45	29.60	29.48	29.69	29.34	29.58	29.19	28.85	28.85
1916	29.47	28.76	29.19	29.34	29.22	29.61	29.51	29.51	29.66	29.50	29.02	28.96	28.76
1917	29.36	28.93	29.44	29.24	29.47	29.75	29.66	29.59	29.49	29.29	29.46	29.20	28.93
1918	28.84	28.88	29.45	29.59	29.51	29.31	29.69	29.72	29.69	29.56	29.05	29.51	28.84
1919	29.33	29.27	29.20	29.65	29.74	29.78	29.59	29.64	29.56	29.55	29.37	29.41	29.20
1920	29.41	29.21	29.03	29.20	29.72	29.54	29.52	29.62	29.35	29.26	29.35	29.35	29.03
1921	29.40	29.43	29.64	29.51	29.70	29.52	29.65	29.61	29.54	29.33	29.50	29.36	29.33
1922	28.92	29.35	29.32	29.38	29.53	29.40	29.67	29.63	29.67	29.50	29.36	29.67	28.92
1923	29.43	29.56	29.15	29.34	29.44	29.32	29.67	29.48	29.74	29.58	29.34	29.29	29.29
1924	29.33	29.62	29.22	29.43	29.26	29.56	29.51	29.45	29.46	29.70	29.20	29.19	29.19
1925	29.19	29.22	29.42	29.57	29.45	29.56	29.64	29.72	29.64	29.10	29.08	29.36	29.08
1926	29.31	29.20	29.19	29.35	29.38	29.59	29.50	29.75	29.79	29.00	29.34	29.50	29.00
1927	29.30	29.39	29.40	29.46	29.53	29.61	29.73	29.70	29.49	29.13	29.02	29.12	29.02
1928	28.90	29.33	29.20	29.36	29.50	29.48	29.67	29.66	29.68	29.55	29.43	29.12	28.90
1929	29.13	29.59	29.01	28.99	29.33	29.49	29.57	29.46	29.74	29.33	29.15	29.42	28.99
1930	29.74	29.62	29.00	29.07	29.57	29.43	29.51	28.87	29.64	29.40	29.07	29.38	28.87
1931	28.96	29.63	29.22	29.30	29.55	29.51	29.43	29.37	29.57	29.28	29.62	29.55	28.96
1932	29.37	29.48	28.64	29.17	29.73	29.45	29.27	29.71	29.40	29.53	29.37	29.34	28.64
1933	29.36	29.31	28.99	29.35	29.51	29.62	29.57	29.53	29.43	29.54	29.11	29.49	28.99
1934	29.04	29.11	29.47	29.24	29.48	29.57	29.71	29.71	29.75	29.51	29.42	29.06	29.04
1935	29.41	29.49	29.48	29.35	29.51	29.48	29.61	29.57	29.49	29.59	29.55	29.44	29.35
1936	29.17	29.40	29.08	29.40	29.51	29.43	29.47	29.68	29.59	29.17	29.34	29.36	29.08
1937	29.55	29.25	29.29	29.49	29.66	29.48	29.57	29.75	29.52	29.34	29.36	29.16	29.16
1938	29.21	29.25	29.35	29.10	29.10	29.65	29.70	29.62	28.41	29.53	29.57	29.30	28.41
Mean	29.20	29.24	29.24	29.38	29.51	29.55	29.59	29.61	29.57	29.42	29.30	29.27	28.95
Minimum	28.55	28.56	28.47	28.99	29.10	29.24	29.27	28.87	28.41	29.00	28.73	28 85	28.41

MEAN TEMPERATURE (IN DEGREES F.)

YEAR	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889	32.9	22.9	37.9	51.1	61.2	67.8	69.5	65.9	62.1	46.4	41.4	34.5	49.5
1890	31.0	32.6	31.9	45.8	56.3	65.2	68.4	67.2	60.4	43.2	36.9	21.8	46.8
1891	26.4	27.6	32.7	47.5	55.6	65.2	66.3	69.0	64.9	48.7	38.1	36.9	48.2
1892	23.6	26.1	31.4	45.2	54.4	69.3	69.3	68.9	59.3	48.6	37.8	26.3	46.7
1893	16.1	22.9	30.4	43.0	55.8	66.9	68.1	69.1	55.8	52.6	38.2	25.5	48.2
1894	26.4	21.5	39.6	46.7	57.3	67.8	72.9	67.9	65.4	51.6	34.8	26.9	48.2
1895	21.5	19.5	31.1	45.6	59.7	69.1	67.5	69.7	64.1	45.6	40.6	30.4	47.0
1896	20.7	25.0	29.2	48.3	61.0	64.0	71.3	68.8	59.5	47.1	42.2	25.6	47.0
1897	24.7	25.4	33.1	47.0	56.7	62.0	71.6	66.8	60.1	49.8	36.2	28.3	46.8
1898	21.8	26.0	39.7	42.4	55.3	66.1	70.9	70.2	63.6	51.1	37.5	25.8	47.5
1899	22.9	21.3	33.6	45.8	57.6	67.8	69.8	68.6	59.4	51.9	37.3	31.0	47.2
1900	24.8	24.6	29.1	45.8	55.1	67.1	71.5	70.6	64.5	55.4	40.8	28.4	48.1
1901	23.6	19.2	32.5	46.4	55.8	66.7	73.3	70.4	62.7	50.7	33.6	26.7	46.8
1902	22.2	25.3	40.5	47.2	56.6	63.1	68.3	66.2	60.9	50.3	42.4	23.7	47.2
1903	24.2	27.2	42.9	47.1	59.8	60.3	69.3	62.4	61.9	51.4	35.1	22.1	47.0
1904	14.3	17.3	30.8	43.2	60.3	65.3	70.4	66.9	60.2	46.0	34.0	19.4	44.0
1905	20.6	17.6	32.8	46.1	57.0	64.3	71.8	66.2	59.8	50.0	36.5	30.1	46.1
1906	30.2	24.1	28.0	45.9	56.9	66.1	71.1	71.2	63.8	51.4	38.7	24.1	47.6
1907	22.1	16.1	35.2	41.7	51.7	63.7	70.4	66.5	62.0	45.7	38.6	31.2	45.4
1908	25.8	20.6	34.8	45.9	59.9	67.2	72.8	67.0	64.0	52.3	38.5	27.6	48.0
1909	25.4	29.3	33.2	45.1	55.7	66.1	68.9	66.8	60.7	48.7	42.0	25.5	47.3
1910	26.2	23.6	40.2	50.4	57.0	63.7	72.2	67.1	61.7	52.3	37.1	21.9	47.8
1911	27.5	22.8	31.7	43.5	62.5	64.4	74.6	68.5	60.4	49.0	37.2	33.5	48.0
1912	14.7	21.4	30.9	46.2	58.8	64.9	71.9	66.4	61.6	53.3	40.5	33.1	46.9
1913	34.2	22.7	38.3	48.0	55.5	66.0	71.6	69.9	60.0	55.5	41.8	32.0	49.6
1914	22.4	17.9	33.7	42.6	58.9	64.6	68.6	69.7	61.0	54.2	37.6	24.7	46.3
1915	27.1	28.9	32.8	51.1	53.8	64.5	69.9	67.0	66.0	52.4	40.8	27.0	48.4
1916	27.7	20.1	26.8	44.6	56.2	61.3	72.5	70.5	61.3	51.7	38.1	26.5	46.4
1917	23.5	19.9	33.4	42.1	49.5	66.3	72.5	72.3	58.4	47.4	34.6	17.1	44.8
1918	13.9	19.6	35.4	46.2	62.2	63.0	71.1	71.6	58.0	53.1	40.0	29.3	46.9
1919	28.7	28.7	38.5	45.7	57.4	68.3	71.8	65.8	61.9	51.6	40.1	23.2	48.5
1920	15.2	21.3	34.3	43.2	54.5	64.7	68.7	71.8	64.1	56.4	36.9	31.0	46.8
1921	26.8	27.5	42.5	52.0	59.0	66.4	74.7	67.2	66.6	50.9	37.9	25.8	49.8
1922	20.1	25.8	35.3	45.8	60.0	67.4	70.8	68.2	64.0	51.7	39.5	25.1	47.8
1923	19.7	17.9	28.6	45.9	56.4	67.9	68.5	67.6	63.9	51.1	39.8	34.8	46.8
1924	25.8	20.7	34.4	44.2	53.2	64.3	71.4	70.3	59.2	51.3	40.5	25.6	46.7
1925	21.1	32.1	39.1	47.5	54.0	69.2	69.1	68.0	61.0	43.5	38.0	29.0	47.6
1926	25.5	22.6	29.4	41.2	55.5	61.6	70.3	69.0	59.8	47.8	39.8	20.1	45.2
1927	22.7	28.7	38.5	45.0	53.9	61.9	70.6	64.9	61.5	54.0	43.9	29.7	47.9
1928	27.3	25.5	33.1	43.3	55.1	63.6	70.3	72.0	59.0	51.8	40.0	32.4	47.8
1929	22.8	25.5	37.8	45.2	56.6	67.1	70.1	66.5	63.1	49.0	39.6	28.1	47.6
1930	26.0	29.2	35.0	44.1	59.1	70.6	69.9	67.8	64.0	48.9	40.2	28.1	48.6
1931	22.9	25.4	36.3	46.7	58.1	66.7	73.1	69.6	64.8	53.6	44.1	31.6	49.4
1932	33.5	26.3	31.9	44.4	57.9	62.9	68.9	70.5	62.5	52.4	36.5	30.2	48.2
1933	32.6	28.6	32.9	45.3	60.5	68.3	72.3	69.3	62.7	49.0	34.5	22.3	48.2
1934	24.0	11.6	30.9	46.2	59.3	67.6	72.4	65.0	64.6	47.7	42.8	26.4	46.7
1935	19.0	24.0	35.8	45.0	54.4	65.6	73.2	69.4	59.1	50.4	43.4	24.9	47.1
1936	23.8	18.1	40.9	43.4	59.4	67.0	70.8	69.7	62.3	50.6	35.7	31.8	47.9
1937	31.7	30.0	31.5	45.0	59.3	66.9	71.6	73.3	60.0	49.6	39.9	27.6	49.0
1938	21.6	28.8	37.4	49.2	55.6	67.1	71.7	72.4	59.4	55.2	41.5	29.7	49.2
Mean	24.2	23.7	34.4	45.7	57.1	65.7	70.8	68.6	61.7	50.5	38.9	27.5	47.4

RANGE OF TEMPERATURE (IN DEGREES F.)

YEAR	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889	48.0	49.0	40.0	46.0	50.0	44.0	31.0	37.0	41.0	43.0	41.0	57.5	92.0
1890	57.0	54.5	69.0	57.5	48.5	47.5	54.0	47.0	52.0	52.0	51.0	48.5	100.5
1891	52.5	60.0	57.5	61.5	62.0	60.0	48.5	47.5	55.5	69.0	60.5	51.5	100.0
1892	66.5	53.5	54.5	58.5	56.0	54.0	52.0	44.0	49.0	54.5	53.0	47.0	104.5
1893	63.0	54.5	48.0	48.5	57.0	52.5	49.5	57.0	51.0	57.0	52.0	64.0	109.0
1894	52.0	66.0	56.0	63.0	56.0	55.5	50.0	54.0	56.0	43.0	55.0	55.0	115.0
1895	50.0	55.0	44.0	56.0	62.5	51.0	54.0	52.0	64.0	51.0	57.0	68.0	105.0
1896	53.0	67.0	52.0	67.5	62.5	51.0	41.0	55.0	57.5	49.0	54.0	62.0	111.0
1897	51.0	59.0	60.5	60.0	48.0	47.5	36.0	43.0	59.5	63.5	58.0	62.5	102.5
1898	65.5	73.0	45.5	54.0	46.0	50.0	56.5	46.5	58.5	59.5	56.0	60.0	115.5
1899	70.5	61.0	42.0	61.0	55.5	51.0	47.0	51.0	51.5	61.5	40.5	59.0	114.5
1900	56.0	64.0	46.0	59.0	67.5	54.0	51.0	53.0	53.5	61.0	55.0	57.5	104.0
1901	55.0	48.5	57.0	58.5	50.5	57.5	52.0	33.5	59.0	51.0	54.0	70.5	111.0
1902	47.5	49.0	48.5	57.5	61.0	49.0	45.0	44.0	51.5	51.5	47.5	64.0	106.0
1903	57.5	68.0	57.0	62.0	68.0	48.5	52.5	42.0	60.5	55.0	68.5	61.5	109.0
1904	66.0	56.0	68.0	50.5	48.0	51.5	48.0	49.5	58.5	59.5	49.0	47.0	120.5
1905	64.0	59.5	76.0	57.0	50.5	54.0	47.0	47.5	53.0	59.0	50.0	51.5	106.0
1906	56.5	57.5	60.5	53.5	58.5	50.5	43.5	43.0	59.5	53.5	43.5	48.5	98.5
1907	78.0	61.5	74.0	49.0	65.0	57.0	46.0	55.0	49.0	52.5	40.5	50.5	119.5
1908	58.5	68.0	62.0	66.0	55.0	55.5	50.5	51.5	55.0	67.5	39.5	63.5	108.0
1909	61.0	57.5	41.0	61.0	49.0	51.5	51.0	56.0	48.0	61.0	53.5	60.0	102.5
1910	65.0	60.5	65.5	56.0	53.0	53.0	48.5	44.5	48.0	65.0	46.0	49.0	106.0
1911	49.0	54.5	56.5	68.0	67.5	45.0	55.0	50.0	55.0	48.5	48.0	52.0	107.0
1912	64.0	66.0	59.5	54.0	55.5	55.0	57.5	50.0	51.0	56.5	48.5	62.0	117.5
1913	48.5	59.5	73.0	62.0	58.5	55.0	59.0	56.0	56.5	54.5	45.0	48.0	104.5
1914	66.0	64.0	60.5	61.5	64.0	51.5	44.0	47.5	72.0	62.5	67.0	77.0	115.0
1915	58.0	49.0	44.5	66.5	46.0	52.0	43.0	46.0	58.5	50.5	49.0	51.0	97.0
1916	62.5	63.5	66.0	45.5	45.5	44.0	47.0	50.5	53.0	58.5	51.5	54.5	111.5
1917	51.0	62.0	60.0	46.0	52.5	38.0	47.0	52.0	54.5	43.0	55.0	63.0	121.0
1918	64.0	73.5	60.5	55.5	50.5	53.0	54.5	56.0	48.5	51.0	47.0	55.0	122.5
1919	62.5	40.5	56.0	56.0	56.0	59.5	49.0	45.0	53.0	54.5	53.0	63.0	110.0
1920	57.5	63.0	71.5	52.5	53.0	43.0	42.5	45.5	53.0	52.0	46.0	54.0	110.0
1921	56.0	59.0	63.5	59.5	56.0	55.5	39.0	46.0	56.0	58.0	44.0	58.0	102.0
1922	53.0	63.0	65.0	57.0	59.5	47.0	45.0	46.5	56.5	68.0	51.5	60.5	107.5
1923	62.5	56.5	64.0	77.5	57.5	55.0	50.5	56.5	56.0	54.5	45.5	50.0	109.0
1924	62.0	47.0	50.0	49.0	41.0	47.5	48.5	55.0	58.0	59.0	70.5	59.0	105.0
1925	54.5	53.0	67.0	56.5	49.5	55.0	44.0	51.5	60.0	53.5	51.0	55.0	110.0
1926	48.0	50.0	57.5	57.5	50.0	51.5	53.0	46.5	49.0	57.0	54.0	53.0	110.0
1927	59.0	48.0	68.0	63.0	44.0	51.5	47.5	38.5	50.0	65.0	50.0	53.0	103.0
1928	58.0	54.0	60.0	62.0	49.5	43.5	46.0	40.0	53.0	66.5	55.0	47.5	96.5
1929	67.0	56.0	64.0	64.0	61.0	57.0	49.0	49.0	64.0	54.0	66.0	45.0	108.0
1930	60.0	71.0	42.0	50.0	57.0	55.0	49.0	50.0	53.0	62.0	60.0	44.0	101.0
1931	58.0	59.0	40.0	52.0	61.0	49.0	41.0	50.0	58.0	54.0	58.0	47.0	107.0
1932	56.0	43.0	46.0	51.0	60.0	53.0	43.0	45.0	60.0	58.0	54.0	75.0	103.0
1933	46.0	70.0	50.0	56.0	54.0	61.0	50.0	51.0	50.0	56.0	57.0	75.0	118.0
1934	48.0	59.0	56.0	48.0	54.0	54.0	44.0	51.0	41.0	44.0	55.0	62.0	115.0
1935	69.0	60.0	61.0	63.0	53.0	44.0	44.0	47.0	52.0	50.0	50.0	45.0	116.0
1936	56.0	58.0	69.0	54.0	59.0	50.0	54.0	44.0	56.0	60.0	66.0	48.0	110.0
1937	49.0	49.0	46.0	47.0	57.0	43.0	46.0	45.0	56.0	55.0	49.0	42.0	90.0
1938	70.0	45.0	79.0	70.0	43.0	49.0	41.0	43.0	51.0	55.0	79.0	52.0	105.0
Mean	58.2	58.0	57.6	57.4	54.9	51.3	47.7	48.1	54.5	56.0	53.0	56.2	107.8

HIGHEST TEMPERATURE (IN DEGREES F.)

YEAR	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889	56.0	47.0	61.0	78.0	88.0	90.0	84.0	82.0	81.0	69.0	61.0	63.0	90.0
1890	61.5	57.5	62.5	79.5	80.0	88.0	94.0	88.5	80.5	78.0	62.5	43.5	94.0
1891	52.0	54.0	56.5	79.5	87.0	94.0	90.0	92.5	91.5	89.0	64.0	60.5	94.0
1892	57.0	46.5	60.5	78.5	84.0	95.0	94.0	94.0	80.0	77.5	67.0	46.0	95.0
1893	50.0	50.0	52.0	67.5	87.0	94.0	90.5	96.0	81.0	80.0	63.0	52.0	96.0
1894	53.0	49.0	73.0	79.0	85.0	93.0	98.0	91.0	91.0	75.0	65.0	51.0	98.0
1895	45.5	45.0	49.0	81.0	92.0	95.0	90.0	90.0	97.0	71.0	72.0	65.0	97.0
1896	41.0	53.0	57.0	88.5	94.5	90.0	91.0	97.0	88.5	72.0	69.0	52.5	97.0
1897	51.0	48.0	59.0	80.5	79.5	85.5	91.0	85.0	91.5	84.0	63.0	59.0	91.5
1898	50.0	54.0	60.0	71.0	78.5	89.5	96.5	91.0	93.0	86.5	62.0	48.0	96.5
1899	49.0	51.0	52.0	82.0	88.5	93.0	90.0	92.0	84.0	82.0	58.0	61.0	93.0
1900	51.5	56.0	49.0	81.0	91.5	94.0	95.5	96.0	89.0	83.0	67.0	58.0	96.0
1901	47.0	44.0	56.5	86.5	82.0	98.5	100.5	86.5	92.0	75.0	60.0	60.0	100.5
1902	47.0	54.0	65.0	83.0	91.0	89.0	90.0	87.0	86.5	74.0	65.0	49.0	91.0
1903	45.5	57.0	76.0	84.0	92.5	86.5	97.0	84.5	91.0	77.5	74.5	52.0	97.0
1904	40.0	48.0	65.0	70.5	85.0	92.5	94.5	89.5	84.5	77.5	56.5	43.5	94.5
1905	51.0	48.5	77.0	79.0	82.5	90.0	93.0	89.0	85.0	80.5	61.0	54.5	93.0
1906	60.0	52.5	53.0	74.5	90.0	87.5	88.5	90.5	91.0	77.5	62.0	45.5	91.0
1907	54.5	43.0	79.5	70.5	90.0	95.0	90.0	96.0	85.0	73.0	60.0	60.5	96.0
1908	53.0	56.0	67.0	84.0	88.5	91.5	96.0	88.5	88.0	90.5	58.0	65.5	96.0
1909	54.0	54.5	54.0	80.0	81.5	91.5	93.0	94.0	83.0	85.0	72.0	51.5	94.0
1910	56.0	53.5	78.0	80.0	84.0	88.0	97.0	85.5	82.0	84.0	61.0	47.0	97.0
1911	50.5	51.5	59.0	86.0	94.5	89.5	104.0	94.5	84.0	72.5	66.5	62.0	104.0
1912	45.0	49.5	60.5	78.0	88.0	91.0	98.5	89.0	86.0	83.0	67.0	65.0	98.5
1913	59.5	55.0	74.0	84.5	89.0	92.0	100.0	97.0	87.5	79.0	68.0	53.0	100.0
1914	52.0	46.5	69.0	83.5	91.0	90.5	89.0	95.0	96.5	84.5	71.5	58.5	96.5
1915	54.0	51.0	57.5	88.0	80.0	89.0	91.0	88.0	93.0	76.0	69.0	53.0	93.0
1916	57.5	47.5	66.0	73.5	81.5	84.0	93.5	95.5	89.5	84.0	64.0	54.5	95.5
1917	47.5	46.0	58.0	71.0	81.0	88.0	98.5	98.0	85.0	70.0	62.0	40.5	98.5
1918	44.0	51.0	69.0	79.5	86.5	93.0	99.5	100.0	84.0	78.5	62.5	52.0	100.0
1919	54.0	49.0	68.0	74.0	89.0	101.0	98.0	88.0	88.0	81.5	70.0	54.0	101.0
1920	41.0	45.0	70.5	74.5	83.5	88.0	87.5	92.0	90.0	81.5	62.0	58.0	92.0
1921	50.0	55.0	79.5	85.0	89.0	96.0	93.5	91.0	92.0	79.5	66.0	57.0	96.0
1922	41.0	49.5	72.0	81.5	87.5	90.0	94.0	90.5	86.5	88.5	66.0	54.0	94.0
1923	50.5	46.0	60.0	86.0	86.5	97.0	94.0	94.0	86.5	81.0	66.5	57.0	97.0
1924	54.0	44.5	58.0	71.0	74.0	87.0	95.5	97.0	90.5	78.5	75.0	58.0	97.0
1925	41.5	57.0	74.0	82.0	80.0	97.0	91.5	90.5	86.0	73.0	62.0	56.5	97.0
1926	48.0	43.0	57.0	75.5	80.0	86.5	100.0	91.5	87.0	81.0	69.0	43.0	100.0
1927	47.0	55.0	74.0	85.0	75.0	89.0	91.0	82.5	84.5	89.0	70.0	61.5	91.0
1928	54.5	50.5	68.0	82.5	80.5	85.0	93.0	92.0	84.0	86.0	73.0	56.0	93.0
1929	56.0	54.0	67.0	86.0	92.0	92.0	94.0	90.0	97.0	76.0	74.0	46.0	97.0
1930	56.0	65.0	56.0	75.0	92.0	92.0	95.0	93.0	88.0	83.0	65.0	45.0	95.0
1931	49.0	48.0	58.0	79.0	91.0	94.0	94.0	96.0	94.0	83.0	72.0	56.0	96.0
1932	66.0	46.0	55.0	75.0	91.0	89.0	89.0	91.0	92.0	79.0	62.0	64.0	92.0
1933	55.0	63.0	57.0	78.0	87.0	97.0	97.0	98.0	85.0	79.0	66.0	55.0	98.0
1934	43.0	37.0	61.0	73.0	86.0	93.0	92.0	89.0	83.0	72.0	67.0	64.0	93.0
1935	48.0	48.0	68.0	86.0	85.0	88.0	95.0	92.0	82.0	73.0	70.0	44.0	95.0
1936	50.0	46.0	72.0	79.0	91.0	90.0	98.0	93.0	88.0	77.0	71.0	55.0	98.0
1937	58.0	55.0	58.0	71.0	92.0	92.0	96.0	95.0	92.0	76.0	63.0	48.0	96.0
1938	58.0	49.0	79.0	88.0	77.0	91.0	88.0	93.0	87.0	85.0	75.0	56.0	93.0
Mean	51.1	50.5	63.8	79.4	86.1	91.2	93.9	91.6	87.7	79.4	66.0	54.3	95.7
Highest	66.0	65.0	79.5	88.5	94.5	101.0	104.0	100.0	97.0	90.5	75.0	65.5	104.0

LOWEST TEMPERATURE (IN DEGREES F.)

YEAR	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889	8.0	—2.0	21.0	32.0	38.0	46.0	54.0	45.0	40.0	26.0	20.0	5.5	—2.0
1890	4.5	3.0	—6.5	22.0	31.5	40.5	40.0	41.5	28.5	26.0	11.5	—5.0	—6.5
1891	—0.4	—6.0	—1.0	18.0	25.0	34.0	41.5	45.0	36.0	20.0	3.5	9.0	—6.0
1892	—9.5	—7.0	6.0	20.5	28.0	41.0	42.0	50.0	31.0	23.0	14.0	—1.0	—9.5
1893	—13.0	—4.5	4.0	19.0	30.0	41.5	41.0	39.0	30.0	23.0	11.0	—12.0	—13.0
1894	1.0	—17.0	17.0	16.0	29.0	37.5	48.0	37.0	35.0	32.0	10.0	—4.0	—17.0
1895	—4.5	—10.0	5.0	25.0	29.5	44.0	46.0	38.0	33.0	20.0	15.0	—3.0	—10.0
1896	—12.0	—14.0	5.0	21.0	32.0	39.0	50.0	42.0	31.0	23.0	15.0	—9.5	—14.0
1897	0.0	—11.0	—1.5	20.5	31.5	38.0	55.0	42.0	32.0	20.5	5.0	—3.5	—11.0
1898	—15.5	—19.0	14.5	17.0	32.5	39.5	40.0	44.5	34.5	27.0	6.0	—12.0	—19.0
1899	—21.5	—10.0	10.0	21.0	33.0	42.0	43.0	41.0	32.5	20.5	17.5	2.0	—21.5
1900	—4.5	—8.0	3.0	21.0	24.0	40.0	44.5	43.0	35.5	22.0	12.0	0.5	—8.0
1901	—8.0	—4.5	—0.5	28.0	31.5	41.0	48.5	53.0	33.0	24.0	6.0	—10.5	—10.5
1902	—0.5	5.0	16.5	25.5	30.0	40.0	45.0	43.0	35.0	22.5	17.5	—15.0	—15.0
1903	—12.0	—11.0	19.0	22.0	24.5	38.0	44.5	42.5	30.5	22.5	6.0	—9.5	—12.0
1904	—26.0	—8.0	—3.0	20.0	37.0	44.0	46.5	40.0	26.0	18.0	7.5	—3.5	—26.0
1905	—13.0	—11.0	1.0	22.0	32.0	36.0	46.0	41.5	32.0	21.5	11.0	3.0	—13.0
1906	3.5	—5.0	—7.5	21.0	31.5	37.0	45.0	47.5	31.5	24.0	18.5	—3.0	—7.5
1907	—23.5	—18.5	5.5	20.5	25.0	38.0	44.0	41.0	36.0	20.5	19.5	10.0	—23.5
1908	—5.5	—12.0	5.0	18.0	33.5	36.0	46.0	37.0	33.0	23.0	18.5	2.0	—12.0
1909	—7.0	—3.0	13.0	19.0	32.5	40.0	42.0	38.0	35.0	24.0	18.5	—8.5	—8.5
1910	—9.0	—7.0	12.5	24.0	31.0	35.0	48.5	41.0	34.0	19.0	15.0	—2.0	—9.0
1911	1.5	—3.0	2.5	18.0	27.0	44.5	49.0	44.5	29.0	24.0	18.5	10.0	—3.0
1912	—19.0	—16.5	1.0	24.0	32.5	36.0	41.0	39.0	35.0	26.5	18.5	3.0	—19.0
1913	11.0	—4.5	1.0	22.5	30.5	37.0	41.0	41.0	31.0	24.5	23.0	5.0	—4.5
1914	—14.0	—17.5	8.5	22.0	27.0	39.0	45.0	47.5	24.5	22.0	4.5	—18.5	—18.5
1915	—4.0	2.0	13.0	21.5	34.0	37.0	48.0	42.0	34.5	25.5	20.0	2.0	—4.0
1916	—5.0	—16.0	0.0	28.0	36.0	40.0	46.5	45.5	36.5	25.5	12.5	0.0	—16.0
1917	—3.5	—16.0	—2.0	25.0	28.5	50.0	51.5	46.0	30.5	27.0	7.0	—22.5	—22.5
1918	—20.0	—22.5	8.5	24.0	36.0	40.0	45.0	44.0	34.5	27.5	15.5	—3.0	—22.5
1919	—8.5	8.5	12.0	18.0	33.0	41.5	49.0	43.0	35.0	27.0	17.0	—9.0	—9.0
1920	—16.5	—18.0	—1.0	22.0	30.5	45.0	45.0	46.5	37.0	29.5	16.0	4.0	—18.0
1921	—6.0	—4.0	16.0	25.5	33.0	40.5	54.5	45.0	36.0	21.5	22.0	—1.0	—6.0
1922	—12.0	—13.5	7.0	24.5	28.0	43.0	49.0	40.0	30.0	20.5	14.5	—6.5	—13.5
1923	—12.0	—10.5	—4.0	8.5	29.0	42.0	43.5	37.5	30.5	26.5	21.0	7.0	—12.0
1924	—8.0	—2.5	8.0	22.0	33.0	39.5	47.0	42.0	32.5	19.5	4.5	—1.0	—8.0
1925	—13.0	4.0	7.0	25.5	30.5	42.0	47.5	39.0	26.0	20.5	11.0	1.5	—13.0
1926	0.0	—7.0	—0.5	18.0	30.0	35.0	47.0	45.0	38.0	24.0	15.0	—10.0	—10.0
1927	—12.0	7.0	6.0	22.0	31.0	37.5	43.5	44.0	34.5	24.0	20.0	8.5	—12.0
1928	—3.5	—3.5	8.0	20.5	31.0	41.5	47.0	52.0	31.0	19.5	14.5	8.5	—3.5
1929	—11.0	—1.0	3.0	22.0	31.0	35.0	45.0	41.0	33.0	22.0	7.0	1.0	—11.0
1930	—4.0	—6.0	14.0	25.0	35.0	37.0	46.0	43.0	35.0	21.0	5.0	1.0	—6.0
1931	—9.0	—11.0	18.0	27.0	30.0	45.0	53.0	46.0	36.0	29.0	14.0	9.0	—11.0
1932	10.0	3.0	9.0	24.0	31.0	36.0	46.0	46.0	32.0	21.0	8.0	—11.0	—11.0
1933	9.0	—7.0	7.0	22.0	33.0	36.0	47.0	47.0	35.0	23.0	9.0	—20.0	—20.0
1934	—5.0	—22.0	5.0	25.0	32.0	39.0	48.0	38.0	42.0	28.0	12.0	2.0	—22.0
1935	—21.0	—12.0	7.0	23.0	32.0	44.0	51.0	45.0	30.0	23.0	20.0	—1.0	—21.0
1936	—6.0	—12.0	3.0	25.0	32.0	40.0	44.0	49.0	32.0	17.0	5.0	7.0	—12.0
1937	9.0	6.0	12.0	24.0	35.0	49.0	50.0	50.0	36.0	21.0	14.0	6.0	6.0
1938	—12.0	4.0	0.0	18.0	34.0	42.0	47.0	50.0	36.0	30.0	—4.0	4.0	—12.0
Mean	—7.1	—7.4	6.1	22.0	31.2	40.0	46.4	43.4	33.2	23.4	12.9	—1.9	—12.2
Lowest	—26.0	—22.5	—7.5	8.5	24.0	34.0	40.0	37.0	24.5	17.0	—4.0	—22.5	—26.0

Mean Relative Humidity*

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889	79.0	90.0	75.0	78.3	73.8	79.1	78.2	80.4	83.3	75.7	75.4	75.2	78.6
1890	68.2	74.8	77.3	64.7	67.1	71.3	70.1	74.9	80.9	68.2	67.8	67.2	71.1
1891	72.2	69.4	63.7	60.1	59.3	65.3	66.1	70.3	72.1	65.5	68.7	68.7	66.8
1892	73.7	72.8	64.1	54.5	60.3	68.9	65.6	74.9	70.7	65.5	71.0	70.3	67.7
1893	80.2	74.7	71.4	64.8	66.0	71.1	64.8	70.7	72.8	67.0	68.8	80.9	71.1
1894	78.8	77.5	67.5	60.5	65.8	68.1	68.2	69.9	74.4	82.7	70.8	79.0	71.9
1895	82.5	83.9	80.6	68.1	65.0	68.5	72.7	72.7	73.7	69.2	80.5	75.4	74.4
1896	73.3	87.5	85.3	62.0	62.5	67.3	73.1	79.9	84.0	85.0	82.3	79.8	76.9
1897	77.1	75.7	78.9	68.2	71.5	73.3	80.1	79.6	76.6	68.7	83.2	83.9	76.4
1898	85.2	83.1	72.6	72.1	78.4	77.1	79.3	82.1	80.0	83.6	83.4	80.2	79.8
1899	77.7	82.5	79.1	69.2	70.3	74.0	75.2	74.1	74.0	75.9	76.2	79.4	75.6
1900	75.1	77.4	67.8	64.7	65.5	69.5	71.1	75.9	73.1	77.0	75.9	74.9	72.3
1901	74.3	68.5	70.8	68.1	68.1	65.5	72.3	76.3	76.8	70.5	71.1	69.8	71.0
1902	66.2	66.8	72.3	67.1	63.4	70.8	77.2	76.3	79.1	70.9	75.6	72.5	71.6
1903	72.0	77.7	76.4	64.7	61.3	81.1	71.4	78.2	75.0	74.5	73.5	76.5	73.5
1904	85.5	77.7	74.4	70.8	69.7	77.0	77.7	80.5	81.8	74.0	77.5	77.8	77.0
1905	77.2	75.1	76.7	66.7	68.2	78.8	79.1	82.5	83.2	75.9	73.5	80.6	76.5
1906	74.8	77.4	73.9	70.3	70.9	79.1	82.4	82.9	80.1	84.1	72.2	77.0	77.1
1907	76.1	80.2	73.4	74.1	75.3	76.9	76.4	74.9	83.0	77.7	85.9	80.4	77.9
1908	73.8	84.8	77.9	64.3	74.8	66.2	76.6	79.0	79.1	79.0	79.6	75.1	75.8
1909	78.5	78.9	81.3	76.3	71.2	73.6	71.8	78.1	83.1	76.1	77.2	75.2	76.8
1910	80.9	81.3	72.8	69.1	71.6	75.4	70.3	76.3	82.7	75.0	78.7	78.4	76.0
1911	78.8	77.6	73.2	65.2	72.2	74.5	70.7	77.5	82.4	79.0	73.5	77.3	75.2
1912	81.3	78.4	80.3	77.2	78.5	70.0	71.5	78.3	84.0	74.9	77.2	75.4	77.3
1913	79.0	74.5	79.3	74.4	73.0	68.4	70.5	74.2	80.2	79.2	74.0	81.2	75.7
1914	81.4	72.0	76.4	75.5	74.5	76.1	80.7	80.3	74.3	75.3	69.6	73.2	75.8
1915	80.8	78.9	65.4	67.8	66.8	71.4	82.1	85.0	80.8	81.6	74.7	71.6	75.6
1916	81.4	79.9	86.8	81.2	71.9	75.7	81.8	80.7	81.3	78.4	82.3	81.7	80.3
1917	82.4	82.7	77.8	74.6	70.4	78.3	79.4	80.0	83.5	79.6	71.1	76.9	78.1
1918	77.1	76.0	71.9	69.2	72.2	72.9	74.5	75.5	81.3	80.5	81.3	84.5	76.4
1919	79.6	78.6	70.6	68.1	70.8	73.9	77.1	77.3	84.2	83.8	79.1	87.1	77.5
1920	87.7	82.9	78.2	72.5	71.1	77.5	77.6	84.3	83.9	86.7	73.9	73.7	79.2
1921	72.2	68.4	72.4	76.9	75.2	70.9	83.6	77.8	79.5	76.3	80.3	78.5	76.0
1922	78.5	80.5	77.6	73.2	72.2	85.9	80.6	81.6	83.4	75.5	73.4	81.8	78.7
1923	80.1	73.2	76.3	65.3	66.9	70.2	75.2	77.0	81.5	81.5	81.5	77.4	75.5
1924	79.9	77.5	70.2	66.9	70.3	73.8	73.5	76.2	80.1	72.9	70.9	74.6	73.9
1925	81.5	82.8	78.4	78.2	79.3	78.1	81.6	84.3	83.9	80.0	77.8	79.9	80.5
1926	79.4	78.1	75.4	75.0	81.6	78.9	74.1	82.7	83.5	84.2	80.8	78.9	79.4
1927	85.3	85.3	75.2	68.7	83.9	80.2	88.8	87.3	89.0	85.3	84.3	81.3	82.9
1928	78.9	77.2	80.2	76.8	77.1	82.6	80.6	86.3	85.2	79.2	78.1	77.0	79.9
1929	71.1	77.3	71.3	69.0	60.8	66.3	66.0	65.0	72.4	64.0	71.4	76.0	69.2
1930	74.1	66.9	61.6	59.0	60.8	69.1	70.4	71.6	74.8	73.0	73.0	72.0	69.0
1931	73.4	73.3	67.4	55.0	63.0	64.9	70.0	72.9	70.6	66.4	71.7	63.0	67.6
1932	70.9	69.6	59.5	60.1	53.8	63.2	65.9	67.0	68.0	70.0	63.3	68.6	64.9
1933	63.4	61.0	60.3	62.8	60.9	65.3	69.0	74.1	75.8	68.0	65.0	67.4	66.0
1934	64.3	58.0	60.7	58.9	58.6	65.9	65.9	68.6	77.7	72.7	74.3	72.7	66.5
1935	73.3	72.4	67.8	65.7	60.0	72.0	72.7	69.7	73.0	64.9	74.3	64.7	69.2
1936	67.3	64.1	71.2	65.7	61.6	65.6	63.7	67.9	76.2	74.2	68.0	70.7	68.0
1937	73.5	64.0	60.1	61.6	65.8	70.6	68.3	75.1	74.5	69.6	69.8	65.1	68.2
1938	69.9	59.5	61.7	58.5	61.6	66.0	71.8	70.0	72.7	67.1	74.8	73.3	67.3
Mean	70.1	66.6	64.2	61.6	60.7	66.9	68.4	70.2	73.6	69.0	70.6	69.4	67.6

*Mean relative humidity records are based on readings taken at 7 a.m., 2 p.m. and 9 p.m. from 1889 to 1903; and at 8 a.m. and 8 p.m. from 1904 to 1928. From 1929 to 1938 they are based on readings taken at 8 a.m., noon, and 8 p.m. The means are based on the last 10 years.

Mean Percent of Cloudiness

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889	55	40	63	55	42	53	54	43	65	60	68	61	55
1890	52	66	66	50	59	50	56	57	59	64	47	53	57
1891	61	59	55	49	54	47	54	58	50	54	50	51	53
1892	63	55	45	42	66	50	35	53	29	46	58	45	49
1893	52	57	46	55	55	58	44	45	46	40	49	54	50
1894	53	53	55	53	52	54	50	44	53	44	50	44	50
1895	51	39	55	54	46	48	58	44	42	42	61	45	49
1896	43	63	54	39	40	47	50	40	52	63	59	42	49
1897	46	51	56	46	47	47	64	42	39	39	71	68	51
1898	66	64	53	68	65	57	53	60	48	62	60	66	60
1899	53	58	66	42	54	54	50	57	47	60	53	52	54
1900	52	62	47	46	54	49	48	49	54	64	72	62	55
1901	58	45	68	75	70	48	63	67	51	48	65	65	60
1902	60	63	66	68	58	62	66	50	57	51	62	60	60
1903	61	53	63	50	36	71	52	63	42	58	41	49	53
1904	55	42	57	52	45	59	55	47	54	42	43	57	51
1905	58	31	46	43	56	61	55	56	48	36	42	56	49
1906	51	44	49	49	47	54	53	50	32	52	53	66	50
1907	58	41	44	53	68	50	42	36	64	30	48	51	49
1908	37	42	48	42	50	28	47	45	27	37	46	49	41
1909	61	60	49	52	56	44	33	35	55	49	56	45	50
1910	60	57	49	56	66	59	34	47	55	44	68	55	54
1911	62	55	49	42	55	54	42	61	53	59	60	63	55
1912	55	36	53	64	64	43	46	50	60	40	51	58	52
1913	63	42	62	55	53	35	39	41	47	63	53	45	50
1914	63	42	53	56	42	48	69	61	27	44	41	54	50
1915	51	51	27	46	46	41	49	63	53	44	44	55	43
1916	44	59	43	65	53	62	57	54	45	43	51	53	53
1917	64	45	50	46	50	49	48	50	39	55	34	46	48
1918	44	45	36	52	51	45	44	37	56	52	49	55	47
1919	52	38	51	50	50	43	45	44	54	57	53	39	48
1920	49	52	41	51	39	51	50	55	52	48	65	57	51
1921	42	63	59	62	36	43	66	40	39	42	66	45	50
1922	38	54	49	40	34	56	48	58	41	32	40	54	45
1923	58	43	40	38	30	38	42	27	50	44	48	52	45
1924	49	32	44	47	54	40	31	33	47	18	44	57	41
1925	51	45	48	34	54	53	51	37	57	53	47	56	49
1926	55	49	43	49	49	43	52	60	59	54	49	52	51
1927	55	66	46	34	60	48	60	55	48	39	72	50	53
1928	54	49	52	50	54	63	50	60	52	34	53	47	51
1929	46	47	50	60	48	44	40	47	58	55	62	71	52
1930	69	57	48	48	60	54	50	50	51	45	64	67	55
1931	51	55	65	53	66	57	62	55	49	49	68	52	57
1932	78	64	56	57	49	53	50	39	47	67	59	70	57
1933	69	57	60	63	61	49	58	54	57	51	61	66	59
1934	61	43	55	50	53	52	55	52	70	46	63	56	55
1935	59	56	47	65	55	54	58	50	57	43	71	53	56
1936	50	48	59	63	41	54	51	51	57	48	48	62	53
1937	63	44	46	57	59	66	63	60	44	52	55	54	55
1938	62	65	58	52	53	66	55	52	58	40	61	59	57
Mean	55.3	50.9	51.8	51.8	52.1	51.1	50.9	49.7	49.9	48.0	55.1	54.9	51.7

HOURS OF BRIGHT SUNSHINE

YEAR	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Possible hours . .	294	296	371	402	453	457	462	429	373	341	293	283	4,454
1889	134	183	138	191	270	277	182	194	120	129	84	108	2,010
1890	112	131	160	245	225	264	289	199	166	129	143	131	2,194
1891	126	124	195	240	226	248	222	204	224	150	141	143	2,243
1892	128	138	196	244	183	218	287	201	234	178	110	144	2,261
1893	130	111	172	166	188	209	259	225	185	182	133	112	2,072
1894	120	121	150	174	208	180	237	238	176	160	128	159	2,051
1895	153	187	172	188	243	246	192	251	254	197	111	169	2,363
1896	157	168	210	258	297	263	260	254	189	115	105	172	2,448
1897	144	154	188	239	236	248	214	274	221	209	90	108	2,325
1898	132	138	200	168	200	270	236	201	218	157	126	113	2,159
1899	151	147	134	280	221	235	259	206	200	140	130	142	2,245
1900	167	120	216	227	235	259	260	226	177	136	86	108	2,217
1901	117	172	93	103	159	254	208	160	215	178	100	107	1,866
1902	120	138	143	139	210	179	185	209	149	164	109	119	1,864
1903	114	145	138	199	311	102	247	169	236	154	182	129	2,126
1904	144	173	172	182	256	256	274	292	204	183	148	115	2,401
1905	119	178	216	247	286	247	263	242	186	209	156	128	2,477
1906	128	183	225	269	288	316	278	266	254	189	155	111	2,660
1907 . . .	130	200	245	268	209	217	297	217	110	177	125	122	2,317
1908	154	200	220	277	282	362	308	268	242	186	111	133	2,743
1909	127	157	232	220	263	300	290	241	192	194	146	148	2,510
1910	119	180	275	286	287	279	371	229	245	229	137	156	2,793
1911	145	132	236	296	320	280	297	227	195	124	74	105	2,431
1912	149	180	224	198	214	314	260	238	156	163	146	148	2,390
1913	179	205	182	211	221	312	324	282	182	91	113	121	2,423
1914	95	178	170	194	324	283	241	209	246	164	113	160	2,377
1915	144	115	290	223	273	269	191	152	181	162	118	106	2,224
1916	140	140	217	123	181	156	184	259	255	228	141	127	2,151
1917	131	180	232	294	317	250	285	287	240	142	170	156	2,684
1918	173	154	252	235	258	265	286	276	187	180	108	158	2,532
1919	166	216	232	249	282	326	323	259	179	148	123	120	2,623
1920	214	214	242	218	281	241	322	262	243	196	86	143	2,662
1921	167	177	207	215	305	316	285	317	251	206	97	152	2,695
1922	190	147	178	228	334	266	307	256	231	190	109	86	2,522
1923	76	133	192	250	325	360	358	308	224	232	153	162	2,773
1924	175	221	292	288	265	313	336	280	188	225	135	120	2,838
1925	124	141	191	240	242	297	288	280	182	128	127	121	2,361
1926	146	148	219	195	213	246	302	205	159	136	89	130	2,188
1927	123	110	188	208	137	201	206	197	233	215	66	100	1,984
1928	132	176	214	236	227	171	249	203	170	167	121	135	2,201
1929	139	135	157	142	241	253	219	152	175	186	119	92	2,010
1930	117	180	236	273	286	314	298	281	241	185	116	100	2,627
1931	152	135	169	220	201	252	180	193	248	203	89	113	2,155
1932	74	123	178	212	291	261	296	286	253	167	148	105	2,394
1933	151	183	169	186	250	289	275	217	159	179	82	63	2,203
1934	96	191	194	239	289	282	287	222	106	210	140	138	2,394
1935	147	124	198	191	224	179	307	254	179	203	71	162	2,239
1936	163	169	170	177	308	252	323	266	185	174	161	118	2,466
1937	112	138	235	208	241	169	319	216	219	191	132	146	2,326
1938	119	110	189	256	262	296	248	276	165	232	152	126	2,431
Mean . . .	137	158	199	220	252	257	268	237	201	175	121	128	2,353
Mean percent .	46.6	53.4	53.6	54.7	55.6	54.0	58.0	55.2	54.9	51.3	41.3	45.2	52.8
Extremes .	214 74	221 110	292 93	296 103	334 137	362 102	371 180	317 152	255 106	232 91	182 66	172 63	2,838 1,864

PRECIPITATION (IN INCHES)

YEAR	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889	3.29	1.45	1.46	2.42	4.71	5.01	10.52	2.72	3.17	4.58	6.04	3.57	48.94
1890	2.61	4.19	5.37	1.73	5.39	1.53	5.63	4.88	5.85	7.13	1.32	2.86	48.49
1891	6.75	4.23	2.99	2.66	1.97	4.75	5.28	4.18	2.66	2.94	2.99	5.40	46.80
1892	5.85	1.90	2.40	.76	6.28	3.46	4.41	6.47	2.16	.66	4.98	1.01	40.34
1893	3.33	5.75	3.66	4.41	5.02	3.32	2.59	3.49	2.82	4.88	2.81	4.86	46.94
1894	2.16	1.74	1.77	1.83	4.00	3.13	1.55	.31	4.63	4.85	3.14	3.53	32.64
1895	3.87	1.05	2.71	5.56	2.07	2.76	3.87	3.46	5.04	4.77	5.36	3.94	44.46
1896	1.07	4.67	6.11	1.32	2.58	2.57	4.96	3.84	5.41	3.23	3.03	.87	39.66
1897	3.00	2.52	3.53	2.42	4.38	6.65	14.51	4.29	1.94	.73	5.85	7.23	57.05
1898	7.15	3.80	1.63	3.73	5.61	3.69	4.09	6.85	3.65	6.27	5.48	2.30	54.25
1899	2.80	3.56	7.13	1.79	1.28	4.13	4.89	2.00	7.90	1.84	2.17	2.00	41.49
1900	4.08	8.12	5.76	1.85	3.78	3.65	4.67	4.11	3.67	3.72	5.87	2.40	51.68
1901	1.81	.62	5.66	5.95	6.91	.87	3.86	6.14	4.17	3.88	2.08	7.77	49.72
1902	1.72	3.54	5.29	3.31	2.32	4.54	4.66	4.65	5.83	5.59	1.27	4.27	46.99
1903	3.28	4.27	6.40	2.30	.48	7.79	4.64	4.92	1.66	2.72	2.04	3.95	44.45
1904	4.74	2.45	4.48	5.73	4.55	5.35	2.62	4.09	5.45	1.74	1.35	2.75	45.30
1905	3.90	1.70	3.66	2.56	1.28	2.86	2.63	6.47	6.26	2.27	2.06	3.15	38.80
1906	2.18	2.73	4.90	3.25	4.95	2.82	3.45	6.42	2.59	5.69	1.98	4.49	45.45
1907	2.73	1.92	1.82	1.98	4.02	2.61	3.87	1.44	8.74	5.00	4.50	3.89	42.52
1908	2.25	3.53	2.86	1.97	4.35	.76	3.28	4.27	1.73	1.57	1.06	3.05	30.68
1909	3.56	5.16	3.01	5.53	3.36	2.24	2.24	3.79	4.99	1.23	1.06	2.95	39.12
1910	6.14	5.08	1.37	3.07	2.67	2.65	1.90	4.03	2.86	.93	3.69	1.72	36.11
1911	2.36	2.18	3.80	1.87	1.37	2.02	4.21	5.92	3.41	8.81	3.84	4.42	44.21
1912	2.18	3.16	5.70	3.92	4.34	.77	2.61	3.22	2.52	2.07	4.03	4.04	38.56
1913	3.98	2.94	6.38	3.30	4.94	.90	1.59	2.26	2.56	5.16	2.11	3.38	39.50
1914	3.72	3.36	5.52	6.59	3.56	2.32	3.53	5.11	.52	2.09	2.62	2.89	41.83
1915	6.52	7.02	.12	3.99	1.20	3.00	9.13	8.28	1.37	2.89	2.20	5.86	51.58
1916	2.56	5.27	3.97	3.69	3.21	5.34	6.85	2.49	5.08	1.01	3.29	2.85	45.61
1917	3.64	1.98	4.08	1.83	4.13	5.27	3.36	7.06	2.42	6.60	.63	2.56	43.56
1918	4.11	2.99	2.91	2.78	2.47	4.01	1.84	2.22	7.00	1.32	2.87	2.95	37.47
1919	2.02	2.80	4.22	2.37	6.20	1.09	4.17	4.81	4.45	1.81	6.20	1.48	41.62
1920	2.74	4.45	3.63	4.71	3.65	6.26	2.06	3.62	6.74	1.54	5.62	6.02	51.04
1921	2.00	2.38	3.57	6.47	4.56	3.87	6.00	2.35	1.84	1.08	6.20	1.90	42.22
1922	1.56	3.02	5.34	2.81	5.47	9.68	4.28	4.25	2.27	2.55	1.56	3.15	45.94
1923	6.02	1.81	1.98	3.19	3.26	2.24	1.77	2.55	1.89	5.50	5.05	4.23	39.49
1924	3.85	2.56	1.05	4.54	2.21	1.28	1.75	3.11	5.87	.01	2.57	2.16	30.96
1925	3.42	3.64	4.12	3.10	2.55	4.28	6.97	1.93	3.09	4.74	3.23	3.56	44.63
1926	3.23	5.01	3.95	3.62	1.19	2.03	3.24	3.97	1.50	5.02	5.38	2.78	40.92
1927	2.50	2.62	1.96	1.60	4.83	3.37	3.40	5.01	2.79	4.59	8.64	5.65	46.96
1928	2.19	2.90	1.17	4.16	3.25	6.97	6.23	8.40	3.07	.87	1.88	.97	42.06
1929	4.33	3.92	3.20	6.89	4.17	3.06	.70	1.54	3.62	2.75	2.73	4.05	40.96
1930	2.57	1.39	3.95	1.41	3.34	4.47	4.50	1.82	2.08	2.24	3.42	1.63	32.82
1931	3.58	1.80	3.79	2.95	7.44	4.24	3.87	6.57	2.50	3.06	1.55	3.83	45.18
1932	3.67	2.70	4.24	2.33	1.67	2.62	3.83	2.67	3.96	3.69	6.05	1.99	39.42
1933	2.44	3.58	4.79	5.03	1.69	3.68	2.25	6.63	12.34	3.90	1.19	2.81	50.33
1934	3.50	2.82	3.60	4.44	3.42	4.67	1.73	3.02	9.54	2.35	3.46	2.99	45.54
1935	4.96	2.50	1.48	2.54	2.17	5.50	3.10	.82	4.67	.88	4.41	1.05	34.08
1936	6.47	2.64	7.04	4.07	1.76	3.28	1.45	4.85	3.80	4.90	2.02	5.96	48.24
1937	5.38	2.23	3.38	4.03	6.09	5.72	2.88	4.91	3.24	4.33	4.86	2.44	49.49
1938	6.60	1.77	2.00	3.07	3.81	8.45	7.45	2.04	14.55	2.49	2.82	3.95	59.00
Mean	3.61	3.19	3.70	3.35	3.60	3.75	4.10	4.08	4.24	3.29	3.41	3.39	43.70
Extremes	7.15	8.12	7.13	6.89	7.44	9.68	14.51	8.40	14.55	8.81	8.64	7.77	59.00
	1.07	.62	.12	.76	.48	.76	.70	.31	.52	.01	.63	.87	30.68

SNOWFALL (IN INCHES)

YEAR	January	February	March	April	November	December	Annual
1889 . . .	6.50	7.75	4.50	.50	T	6.75	26.00
1890 . . .	4.50	5.00	17.00	T	1.50	15.75	43.75
1891 . . .	17.75	16.00	9.00	11.00	.25	T	54.00
1892 . .	13.00	14.00	8.00	T	4.50	3.00	42.50
1893 . . .	15.25	48.75	3.25	7.00	T	14.75	89.00
1894 . . .	19.50	18.75	2.00	6.00	4.25	21.00	71.50
1895 . . .	21.75	14.50	13.00	0.50	3.00	8.00	60.75
1896	6.50	15.50	17.00	0.50	1.75	3.00	44.25
1897 . . .	21.00	13.00	5.00	T	4.25	9.50	52.75
1898	33.00	15.00	1.50	1.00	8.00	11.00	69.50
1899 . . .	2.00	21.00	27.00	1.00	.50	.50	52.00
1900 . . .	12.50	6.50	13.50	T	1.50	3.00	37.00
1901 . . .	12.00	8.00	6.50	T	.50	25.50	52.50
1902 . . .	11.00	8.25	9.75	T	1.50	26.50	57.00
1903 . . .	8.50	12.00	1.00	T	T	12.00	33.50
1904 . . .	23.50	10.00	11.00	2.00	2.00	11.00	59.50
1905 . . .	21.00	11.00	5.50	T	.50	2.50	40.50
1906 . . .	5.00	13.00	20.25	2.00	4.00	12.00	56.25
1907 . . .	16.50	18.50	3.00	8.00	1.00	7.50	54.50
1908 . . .	1.50	20.00	4.50	T	3.50	9.00	38.50
1909 . . .	8.00	5.00	3.50	T	2.50	12.00	31.00
1910 . .	19.50	18.50	T	0	4.00	2.50	44.50
1911 . .	1.75	11.00	10.50	6.50	1.00	4.50	35.25
1912 . .	13.00	2.50	12.00	1.00	T	5.00	33.50
1913 . .	4.00	11.00	5.00	T	2.50	4.00	26.50
1914 .	9.50	24.50	6.25	5.25	5.75	5.50	56.75
1915 .	11.50	6.50	.50	9.50	.50	11.50	40.00
1916 .	5.00	16.75	22.00	4.75	1.50	9.50	59.50
1917	15.00	11.00	17.00	T	.75	14.25	58.00
1918 .	18.50	11.00	9.50	4.50	T	7.25	50.75
1919 .	6.25	11.50	2.00	T	T	4.75	24.50
1920 .	23.25	31.00	9.75	1.50	5.50	7.00	78.00
1921 .	7.50	20.50	0	1.00	3.00	5.50	37.50
1922 .	14.75	13.50	9.25	2.75	T	18.50	58.75
1923	33.00	12.50	8.00	T	1.00	9.25	63.75
1924 . . .	10.00	12.75	2.25	8.00	9.00	3.00	45.00
1925 . . .	22.00	3.25	1.00	.75	.75	6.75	34.50
1926 . . .	8.50	32.75	9.00	3.25	.25	22.25	76.00
1927 .	11.75	12.00	2.50	2.00	T	3.25	31.50
1928 . . .	4.50	8.50	12.25	2.50	2.00	.25	30.00
1929 .	18.00	15.00	4.50	5.50	3.00	8.00	54.00
1930 .	9.50	5.50	T	T	.75	13.75	29.50
1931 .	20.75	9.50	7.50	2.00	1.00	3.25	44.00
1932 . .	7.75	20.25	8.75	T	T	8.50	45.25
1933 . . .	9.00	19.00	6.00	6.00	7.75	16.00	63.75
1934 . . .	4.00	26.00	5.50	0	T	3.50	39.00
1935 . . .	28.50	9.25	4.00	1.00	3.00	2.00	47.75
1936 . . .	20.50	16.00	4.75	.50	2.75	3.00	47.50
1937 . . .	9.75	.50	6.75	.50	3.00	5.00	25.50
1938 . . .	18.50	6.00	1.25	.25	13.50	3.00	42.50
Mean . . .	13.32	13.99	7.47	2.17	2.34	8.50	47.78
Extremes .	33.00 1.50	48.75 .50	27.00 0.	11.00 0.	13.50 T	26.50 T	89.00 24.50

Season extremes 1892–1893 81.75
1936–1937 23.25

WIND MOVEMENT (IN MILES)

YEAR	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889 . . .	5,101	4,828	7,068	5,648	4,056	4,056	4,032	2,811	4,310	4,762	2,589	4,445	53,706
1890 . . .	4,914	4,616	5,395	5,020	5,284	3,776	3,976	4,116	3,507	4,143	4,228	5,673	54,648
1891 . . .	4,954	4,759	6,261	5,484	4,610	3,713	3,907	3,324	3,201	4,319	5,215	5,465	55,212
1892 . . .	5,059	3,438	7,046	5,370	5,056	4,500	3,365	3,390	3,672	4,071	5,231	4,522	54,720
1893 . . .	4,056	5,242	5,757	5,384	4,833	3,572	3,640	4,126	3,508	4,198	4,179	3,916	52,411
1894 . . .	4,193	4,865	4,406	4,105	2,180	1,838	1,109	1,920	1,414	2,540	4,179	3,508	36,257
1895 . . .	2,896	3,920	4,360	4,098	4,071	3,050	2,934	3,397	3,444	5,029	4,156	5,506	46,861
1896 . . .	4,943	6,445	8,182	4,674	4,838	3,926	4,048	2,968	4,686	4,544	4,654	5,290	59,198
1897 . . .	5,501	4,493	5,363	5,523	5,603	4,208	4,007	3,452	3,506	3,938	4,558	4,068	54,220
1898 . . .	3,494	3,699	3,864	5,477	4,769	4,162	3,377	3,111	2,787	3,999	4,856	4,830	48,425
1899 . . .	4,926	4,427	5,275	3,984	4,219	3,814	3,891	2,522	3,967	2,582	3,361	4,142	47,110
1900 . . .	4,904	5,016	5,602	5,039	4,381	4,101	3,701	2,322	3,042	3,315	4,877	4,203	50,503
1901 . . .	5,224	5,484	5,482	6,211	4,525	3,647	2,763	2,144	2,358	3,652	4,583	4,280	50,353
1902 . . .	4,078	5,199	6,601	4,642	4,328	4,102	2,929	2,386	2,680	4,398	3,077	4,018	48,438
1903 . . .	4,254	4,529	4,169	5,125	3,908	3,130	3,087	2,105	2,890	4,703	3,362	4,994	46,256
1904 . . .	4,112	4,910	4,444	4,902	3,830	3,127	3,268	3,229	3,602	4,160	3,470	3,940	46,994
1905 . . .	5,180	4,503	3,006	4,855	5,004	3,108	3,464	3,030	2,527	3,397	4,317	4,051	46,442
1906 . . .	5,706	4,565	5,686	4,777	3,766	1,409	3,773	3,412	4,249	4,398	5,978	5,554	53,273
1907 . . .	4,987	5,272	5,718	7,096	5,946	4,223	4,114	3,928	3,582	5,111	4,773	5,266	60,016
1908 . . .	7,770	5,511	5,759	8,208	5,818	4,571	3,815	3,802	3,757	3,643	5,485	5,432	63,571
1909 . . .	5,991	5,585	7,034	6,679	5,371	4,225	5,097	3,485	4,008	4,400	5,793	5,845	63,513
1910 . . .	5,786	5,834	5,579	5,533	5,289	3,685	3,812	4,271	3,336	5,467	5,215	5,435	59,242
1911 . . .	6,085	5,515	7,485	5,738	4,939	3,546	3,878	3,029	3,809	3,451	5,950	4,857	58,282
1912 . . .	4,872	4,798	5,291	6,094	5,332	4,533	3,992	3,698	2,980	3,953	5,037	5,337	55,917
1913 . . .	5,359	5,194	6,413	5,659	3,672	3,746	4,315	3,441	3,220	4,698	5,003	4,400	55,120
1914 . . .	5,442	5,855	5,663	6,194	4,491	4,468	3,555	3,198	2,992	3,612	5,280	4,705	55,455
1915 . . .	3,986	4,341	6,864	5,195	4,087	2,439	2,908	3,199	3,332	3,786	5,402	4,947	50,486
1916 . . .	6,341	5,504	5,556	4,836	4,893	3,226	3,126	3,120	3,717	4,176	3,929	4,026	52,450
1917 . . .	4,701	4,485	5,804	3,853	4,610	2,081	2,133	2,548	1,702	4,118	3,721	4,897	44,653
1918 . . .	5,491	5,632	5,791	4,544	4,906	3,858	3,093	2,583	3,271	4,297	3,730	3,239	50,435
1919 . . .	4,554	5,031	7,361	5,374	4,290	3,456	3,719	3,210	3,244	2,914	5,207	4,022	52,382
1920 . . .	4,734	4,791	6,263	6,158	3,703	3,055	3,817	2,802	3,411	3,188	4,268	5,280	51,470
1921 . . .	5,616	3,835	6,486	4,867	4,400	3,832	2,421	3,709	3,568	4,494	4,441	4,704	52,373
1922 . . .	5,353	3,909	4,883	5,661	4,516	3,527	2,847	3,007	2,775	4,670	4,566	4,256	49,970
1923 . . .	4,392	4,013	6,058	6,093	4,519	3,314	2,852	3,312	2,704	3,800	3,379	4,428	48,864
1924 . . .	6,163	3,971	6,600	5,839	5,135	3,190	3,412	3,282	3,274	3,643	4,779	4,597	53,855
1925 . . .	5,688	4,281	4,982	5,268	4,005	4,072	3,292	2,270	3,355	4,231	5,173	6,694	53,311
1926 . . .	4,993	5,273	4,884	6,063	5,150	3,951	2,964	2,375	2,416	3,518	4,608	3,645	49,840
1927 . . .	4,618	4,366	4,483	5,374	3,535	3,475	3,426	2,818	2,515	4,082	5,213	5,546	49,451
1928 . . .	6,419	5,377	6,613	6,770	3,716	3,632	3,545	3,090	3,744	4,512	4,736	5,061	57,215
1929 . . .	7,279	4,005	6,089	5,778	5,417	3,528	3,768	3,839	3,184	4,798	3,883	4,320	55,888
1930 . . .	4,222	3,800	6,828	5,531	4,593	4,180	3,455	3,297	2,922	3,729	4,054	4,355	50,966
1931 . . .	4,256	4,378	5,182	5,674	4,154	3,704	3,158	2,932	3,481	3,761	4,061	5,141	49,882
1932 . . .	4,870	4,430	7,628	5,956	4,566	3,671	3,948	3,301	3,876	4,487	5,363	4,346	56,442
1933 . . .	5,961	6,029	6,988	5,357	4,506	3,874	3,362	3,569	3,236	4,048	4,624	5,150	56,704
1934 . . .	4,758	5,143	4,979	4,768	4,360	3,847	3,087	3,027	2,846	4,406	4,118	5,295	50,634
1935 . . .	5,357	3,864	5,462	5,197	4,435	3,197	3,222	3,251	3,177	4,007	4,781	4,815	50,765
1936 . . .	5,199	4,148	4,432	5,115	4,389	3,720	3,471	3,362	3,879	4,018	4,824	4,665	51,222
1937 . . .	4,339	4,745	5,974	4,888	3,382	2,896	2,725	2,870	2,908	4,636	3,794	3,793	46,950
1938 . . .	3,667	4,925	5,117	4,519	3,797	3,308	3,502	2,980	3,971	3,915	4,493	4,571	48,765
Mean . . .	5,055	4,776	5,764	5,404	4,504	3,585	3,422	3,127	3,271	4,074	4,531	4,710	52,223

MAXIMUM VELOCITY OF WIND (IN MILES PER HOUR)

YEAR	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1906	26	29	26	30	26	18	26	21	21	35	28	30	35
1907	30	33	36	30	21	26	30	21	26	30	30	35	36
1908	35	35	28	33	26	21	39	19	23	30	30	26	39
1909	30	30	37	36	27	26	24	19	26	23	30	28	37
1910	33	28	30	27	26	24	21	16	16	30	26	35	35
1911	41	26	36	37	30	21	26	21	21	21	30	33	41
1912	30	42	19	28	35	21	19	26	18	23	33	30	42
1913	39	30	39	26	26	21	23	21	21	30	33	28	39
1914	32	33	37	37	26	21	26	26	26	21	33	30	37
1915	26	23	30	28	23	21	39	35	39	26	39	39	39
1916	30	30	26	39	30	21	18	16	21	35	33	27	39
1917	30	26	28	33	23	23	21	14	15	30	21	21	33
1918	27	37	32	25	21	21	21	21	21	26	21	21	37
1919	30	26	26	27	23	16	19	19	18	21	26	30	30
1920	26	26	30	29	26	21	23	30	30	33	28	27	33
1921	26	23	24	21	21	21	15	18	26	26	30	30	30
1922	35	26	28	30	23	35	26	18	21	23	27	30	35
1923	24	28	30	30	21	23	16	21	16	26	19	26	30
1924	32	26	30	30	26	19	35	21	26	19	26	26	35
1925	23	30	21	24	21	26	19	16	18	35	30	30	35
1926	35	26	26	26	23	21	26	18	16	27	30	21	35
1927	26	35	30	26	21	26	23	19	21	27	28	26	35
1928	35	21	26	28	23	16	23	26	24	27	39	41	41
1929	38	24	35	35	35	26	33	33	26	35	35	33	38
1930	39	29	30	30	32	32	25	32	25	32	39	32	39
1931	39	39	32	39	28	28	22	32	32	32	28	40	40
1932	39	39	48	39	28	40	28	22	32	32	32	32	48
1933	39	45	45	35	32	36	28	20	28	32	32	40	45
1934	40	48	32	39	35	25	28	22	39	39	28	45	48
1935	40	40	45	40	45	39	28	25	28	39	28	32	45
1936	32	23	27	32	26	36	44	28	28	29	32	26	44
1937	25	48	29	26	25	22	25	22	28	42	32	39	48
1938	47	42	32	40	40	20	28	32	80	39	44	48	80
Mean	32.7	31.7	31.2	31.4	28.8	24.6	28.7	22.7	25.9	29.5	30.3	31.4	39.5
Maximum	47	48	48	40	45	40	44	35	80	42	44	48	80

SNOW, FROST, AND WEATHER

YEAR	Last Snow	First Snow	Last Frost	First Frost	Number of Days of Precipitation	Number of Clear Days	Number of Fair Days	Number of Cloudy Days
1889 . .	April 2	Oct. 13	May 26	Sept. 21	119	94	110	161
1890 . .	April 8	Oct. 19	May 12	Sept. 25	141	137	105	123
1891 . .	May 5	Nov. 26	May 19	Oct. 12	112	145	103	117
1892 . .	April 10	Nov. 5	May 10	Sept. 30	108	123	109	134
1893 . .	April 21	Nov. 4	May 8	Sept. 3	143	101	96	168
1894 . .	April 12	Nov. 8	May 22	Aug. 22	125	107	83	175
1895 . .	April 3	Oct. 20	May 17	Aug. 22	119	118	110	137
1896 . .	April 7	Nov. 14	May 1	Sept. 24	108	132	102	132
1897 . .	April 27	Nov. 12	May 8	Sept. 22	127	108	109	148
1898 . .	April 6	Nov. 24	April 27	Sept. 21	125	78	138	149
1899 . .	April 16	Oct. 12	May 4	Sept. 14	110	91	139	135
1900 . .	April 9	Nov. 9	May 29	Sept. 15	131	83	144	138
1901 . .	April 3	Oct. 18	May 6	Sept. 26	135	81	105	179
1902 . .	April 2	Oct. 29	May 14	Sept. 6	144	73	113	179
1903 . .	April 4	Oct. 26	May 2	Sept. 25	116	119	98	148
1904 . .	April 20	Oct. 12	April 23	Sept. 22	126	142	96	128
1905 . .	May 1	Nov. 9	May 24	Sept. 12	122	130	128	107
1906 . .	April 23	Nov. 11	May 20	Sept. 25	121	130	140	95
1907 . .	May 11	Nov. 24	May 22	Sept. 27	122	95	155	115
1908 . .	April 20	Nov. 5	June 3	Sept. 16	109	143	130	93
1909 . .	April 9	Oct. 17	May 12	Oct. 13	128	112	151	102
1910 . .	March 14	Oct. 27	May 6	Sept. 23	117	142	152	71
1911 . .	April 19	Nov. 14	May 5	Sept. 14	120	106	131	128
1912 . .	April 9	Nov. 3	May 1	Aug. 31	117	71	182	113
1913 . .	April 9	Oct. 31	May 15	Sept. 10	135	105	144	116
1914 . .	April 16	Oct. 27	May 16	Sept. 28	118	100	139	126
1915 . .	April 3	Nov. 17	May 20	Sept. 23	122	82	156	127
1916 . .	April 14	Nov. 15	May 19	Sept. 17	126	121	129	136
1917 . .	May 5	Nov. 24	May 18	Sept. 11	117	129	137	99
1918 . .	April 13	Nov. 4	April 26	Sept. 11	123	106	151	108
1919 . .	April 25	Nov. 5	May 1	Sept. 18	132	130	131	104
1920 . .	April 8	Nov. 12	May 5	Oct. 7	135	113	156	92
1921 . .	April 18	Nov. 7	May 12	Oct. 9	131	126	141	98
1922 . .	April 23	Nov. 24	May 12	Sept. 19	120	117	127	121
1923 . .	April 15	Nov. 8	May 24	Sept. 15	125	141	131	93
1924 . .	April 8	Nov. 9	May 2	Sept. 24	96	141	145	80
1925 . .	April 20	Oct. 10	May 26	Sept. 23	130	98	141	126
1926 . .	April 7	Oct. 18	May 6	Oct. 9	117	83	142	140
1927 . .	April 5	Nov. 10	May 3	Oct. 11	127	59	158	148
1928 . .	April 28	Nov. 8	May 14	Sept. 25	122	93	116	157
1929 . .	April 22	Nov. 21	May 23	Sept. 19	129	99	137	129
1930 . .	April 24	Oct. 25	May 31	Oct. 1	130	163	100	102
1931 . .	April 29	Nov. 27	May 4	Oct. 10	134	126	100	139
1932 . .	April 27	Nov. 26	June 8	Sept. 11	125	150	97	119
1933 . .	April 26	Nov. 6	June 2	Sept. 12	134	126	105	134
1934 . .	March 24	Oct. 13	May 13	Oct. 2	119	138	101	126
1935 . .	April 17	Nov. 17	May 25	Sept. 17	116	137	86	142
1936 . .	April 2	Nov. 24	May 22	Sept. 26	143	169	64	133
1937 . .	April 9	Nov. 19	April 26	Oct. 9	125	139	105	121
1938 . .	April 10	Nov. 14	May 31	Sept. 10	126	153	97	115
Mean .	April 15	Nov. 6	May 14	Sept. 21	124	116	123	126
Extremes	March 14 May 11	Oct. 10 Nov. 27	April 23 June 8	Oct. 13 Aug. 22				

Summary for the Fifty Years 1889 - 1938, Inclusive

BAROMETER (PRESSURE IN INCHES)

[Readings reduced to sea level]

Maximum, Feb. 1, 1920, 10 a.m.	31.050
Minimum, Sept. 21, 1938, 5:05 p.m.	28.410
Mean	30.014
Total range	2.640
Greatest annual range, 1938	2.470
Least annual range, 1933	1.380
Mean annual range	1.850
Greatest monthly range, January 1913	2.180
Least monthly range, August 1894	.440
Mean monthly range	1.087

AIR TEMPERATURE (IN DEGREES F.)

Highest, July 4, 1911, 3:30 p.m.	104.0
Lowest, Jan. 5, 1904, 7:30 a.m.	—26.0
Mean	47.4
Total range	130.0
Greatest annual range, 1918	122.5
Least annual range, 1937	90.0
Mean annual range	107.8
Greatest monthly range, Mar. and Nov. 1938	79.0
Least monthly range, July 1889	31.0
Mean monthly range	54.4
Greatest daily range, Dec. 10, 1902	54.0
Least daily range, Nov. 20, 1937	1.0

HUMIDITY

Mean relative humidity, percent	67.6

PRECIPITATION (IN INCHES)

Greatest annual precipitation, 1938	59.00
Least annual precipitation, 1908	30.68
Mean annual precipitation	43.70
Greatest monthly precipitation, September 1938	14.55
Least monthly precipitation, October 1924	.01
Mean monthly precipitation	3.64
Greatest annual snowfall, 1893	89.00
Least annual snowfall, 1919	24.50
Mean annual snowfall	47.78

WIND (IN MILES)

Greatest annual movement, 1908	63,571
Least annual movement, 1894	36,257
Mean annual movement	52,223

WIND (IN MILES)—Continued

Greatest monthly movement, April 1908	8,208
Least monthly movement, July 1894	1,109
Mean monthly movement	4,352
Greatest daily movement, April 8, 1909	705
Least daily movement, Sept. 29, 1894; Mar. 7, 1890; Jan. 6, 1904; Dec. 4, 1916; Oct. 6, 1920	0
Mean daily movement	146
Maximum velocity for 5 minutes, Sept. 21, 1938, 5:17 p.m	80

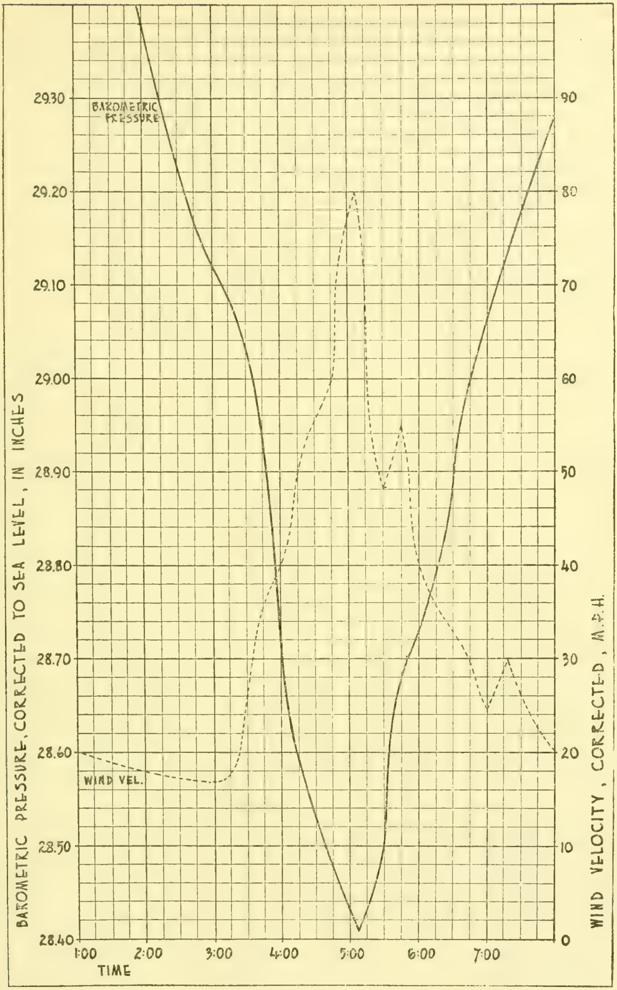
WEATHER

Mean cloudiness observed, percent	51.7
Percent of possible hours bright sunshine	53
Mean annual number of clear days	116
Mean annual number of fair days	123
Mean annual number of cloudy days	126
Mean annual number of days of precipitation	124
Mean date of last snow	April 15
Mean date of first snow	Nov. 6
Mean date of last frost	May 14
Mean date of first frost	Sept. 21

The Hurricane of September 1938

The hurricane on September 21, 1938, was the most disastrous storm during the 50-year period covered by this summary. A reprint of the "Remarks" in the monthly bulletin is given below. The accompanying graph shows barometric pressure and wind velocity in the afternoon of that day.

> The outstanding feature of the weather during September was the heavy rainstorm from the 17th to the 21st, terminating with the hurricane on the 21st. A total of 11.96 inches of rain fell between 6 p.m. on the 17th and 9 p.m. on the 21st. This storm brought the Connecticut River to a height of 14.9 feet over the Holyoke dam. This is .1 foot higher than in November, 1927, and 1.7 feet lower than in March, 1936. The total rainfall during the month was 14.55 inches. This is the greatest rainfall in Amherst during any month since 1836, the year records were first taken in Amherst. The nearest approach to this heavy rainfall was in July, 1897 when 14.51 inches were recorded. The total rainfall since January 1 is now 49.74 inches, as compared with a normal of 33.25 inches for this period.
>
> The barometer continued high during the rain on the 17th and 18th and until noon on the 19th, reading approximately 30.15 inches when reduced to sea level. At noon (E. S. T.) on the 19th the barometer commenced falling slowly and reached 29.70 by 12 p.m. on the 20th. On the 21st the fall of the barometer was accelerated but did not become unusual until noon when it had fallen to 29.58. Between 12 noon and 2 p.m. it fell .15 inches and by 3 p.m. it reached 29.12. By 4 o'clock the barometer had dropped to 28.72 inches and reached the minimum of 28.41 at 5:05 p.m. During this time the wind rose from 20 miles per hour at 3 p.m. to 38 at 4 p.m., and about 50 at 4:30, and reached 80 miles per hour at 5:17. An average velocity of 57 miles per hour was maintained for 5 minutes beginning at 5:10. After 5:05 p.m. the barometer rose at about the same rate at which it had dropped. The wind gradually decreased in velocity to 65 miles per hour at 5:30 and fell to 22 miles per hour at 7 p.m.
>
> On March 1, 1914 there was a sudden drop in the barometer quite similar to that which occurred on the 21st. The lowest reading at that time was 28.47 inches when reduced to sea level. The wind velocity accompanying that storm was only 45 miles per hour.
>
> The wind blew from the north during the rain on the 17th, 18th, 19th and 20th, except from 9 p.m. on the 19th to 6 a.m. on the 20th when it blew from the south. It continued from the north until noon on the 21st when it shifted to southeast and continued from that direction during the storm. After the storm it shifted to south and continued from that direction on the following day.
>
> A large number of trees was uprooted and others were snapped off by the force of the wind, both on the College campus and in the town. Many tobacco barns and poultry buildings were overturned and collapsed. Many roofs were damaged, some blowing off completely. Few substantial buildings were damaged except from falling trees.



Barometric Pressure and Wind Velocity

September 21, 1938

Publication of This Document Approved by Commission on Administration and Finance
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MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

Bulletin No. 368 December, 1939

Cephalosporium Elm Wilt In Massachusetts

By Malcolm A. McKenzie and Eunice M. Johnson

The widespread occurrence of a wilt disease of elm, associated with a fungus of the genus Cephalosporium, became apparent during recent surveys of the State for shade tree pests. This paper reports an attempt to discover whether the disease is specific to the American elm, as well as a study of the entry and development of the fungus within the host.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

CEPHALOSPORIUM ELM WILT IN MASSACHUSETTS

By Malcolm A. McKenzie, Assistant Research Professor of Botany, and
Eunice M. Johnson, Institutional Fellow, Department of Botany[1]

INTRODUCTION

The widespread occurrence, in Massachusetts, of a wilt disease of American elm (*Ulmus americana* L.) associated with a fungus belonging to the genus Cephalosporium as described by Corda, became apparent during recent surveys of the State for shade tree pests. Figure 1 shows an elm in which the disease had reached a rather advanced stage by midsummer. Infections by the causal fungus which occur early in the growing season are frequently particularly destructive. Because of the limited extant knowledge concerning the wilt in elm, it was considered advisable to make further investigations of this disease. Accordingly, studies have been made of the course of the disease in different species and varieties of elm, the relation of the fungus pathogen to the host (including the possible means of fungus entrance, fungus development in the host tissues, and host reaction), and the morphology, physiology, and life-history of the organism. The present report describes the results of these investigations in comparison with previously published reports by various investigators.

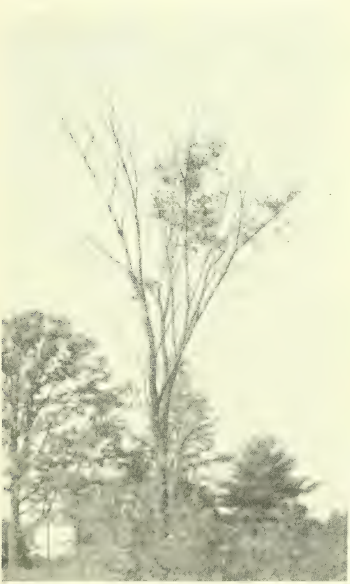

Figure 1. An American Elm in midsummer, from which the fungus, Cephalosporium sp., was isolated in cultural studies.

Photograph by Irving D. Hardy.

The American elm is the most widely planted shade tree in New England. It has been used in street planting since early colonial days and the majority of our old Massachusetts towns have grown up around elm-shaded commons. The elm is as much a part of the tradition of Massachusetts, and of all New

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[1] The writers are indebted to Prof. A. Vincent Osmun, Head of Department of Botany, for his advice and sustained interest during the course of the investigations reported in this publication.

England, as are the familiar white church spires which dot the countryside. The elms not only are a cherished heritage, but also possess a unique beauty which, in the eyes of many, transcends that of any other tree. Moreover, the charm of Massachusetts' elm-planted villages is one of their greatest commercial assets. This has not long been recognized, but is becoming increasingly appreciated as tourist, recreation, and leisure-time activities increase. Since the Dutch elm disease (19)[2] first threatened the elms in America it has become more apparent that all diseases of elm, as well as of other shade trees, deserve much careful study.

REVIEW OF LITERATURE

The genus Cephalosporium does not figure prominently in phytopathological literature, but several species have been reported as occurring saprophytically. Adams and Manns (2) reported *C. sacchari* Adams & Manns, as following corn ear worm in the kernel rot of corn. Young (27) describes *C. acremonium* Corda, in connection with callosities on garden truck. Abbott (1) attributes a leaf spot of coffee to *Cephalosporium* sp. Corda, but considers it of minor importance. In England, *C. malorum* K. and Beaum. was described by Kidd and Beaumont (15) as the cause of rot on apples in cold storage. Another species, *C. carpoginum* Ruehle, was found on apple fruit in the United States by Ruehle (24). Morrow (20) claims that *C. curtipes* Sacc. is very common in forest soils, and Paine (22) finds that members of the genus act as cellulose destroyers. Müller (21) in 1933 reported *C. lecanii* Zimm. on scale insects of Citrus in Brazil, and suggested its cultivation as an insect control measure.

So far as the writers can learn, the only reports of any species of the genus Cephalosporium occurring as an important plant parasite are in association with the wilt or die-back of elm and with a canker of balsam fir. The latter was reported by Christensen (8) as a serious disease in Minnesota and Wisconsin.

The elm wilt disease was discovered rather recently and the literature concerning it is very limited. In 1931 May (17) described a new elm disease which he attributed to infection by the fungus *Cephalosporium* sp. Of 300 elm specimens received by him during the previous year 10 percent were infected with this fungus. He described the symptoms as very similar to those of the diseases caused by species of Graphium and Verticillium. The cultures which he obtained were white, cottony colonies of aerial mycelium, which later became light brown. Spores, usually with one or two oil drops, were hyaline, generally elliptic, variable in shape, and averaged 1.9 by 4.5 microns in size. His specimens had been collected from Iowa, Missouri, New York, Ohio, and Washington, D. C.

Liming (16) found that the trees infected with *Cephalosporium* sp. showed an increase in the diseased condition in the second year. He also stated that out of 1407 trees suspected of the Dutch elm disease, 336 showed a fungus referred to the genus Cephalosporium.

In 1934, Goss and Frink (11) published an account of their studies of the disease, which they found to be common in the city of Lincoln, Nebraska. They inoculated both *U. americana* and *U. pumila* L. but inoculations were not successful in the latter elm. In the former elm, the organism progressed more rapidly upward than toward the root. Greater success was obtained in their experiments when inoculating into roots and trunks, than when inoculating soil or leaves.

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[2] Figures in parentheses refer to Literature Cited, page 23.

Creager (9) reports that, according to his experiments, the most common method of fungus entrance is through wounds in the leaves.

McCormick (18) reports that Cephalosporium wilt is the disease most frequently found in specimens of elm received at the Connecticut Agricultural Experiment Station. She also reports the survival and apparent health of two trees eleven years after successful inoculation, although the causal fungus has been isolated consistently from both trees during the period since inoculation.

Beattie (4) reports that while the disease seems to be very prevalent in the United States, it is unknown in England.

A map and table, showing the geographical distribution of the disease and the number of trees known to be affected in Massachusetts during 1935 and 1936 were published by the junior author in 1937 (14).

A pycnidial stage of the fungus has been reported by Verrall and May (25), and they have placed it in the genus Dothiorella. Creager (9, 10) also reports pycnidia as being abundant both in nature and in laboratory cultures. Reports on the finding of pycnidial stages of fungi associated with some other diseases affecting woody parts of elms in the United States include *Phomopsis* sp.[3], *Coniothyrium ulmi* (12), *Sphaeropsis ulmicola* (13), and *Vermicularia* sp. (12).

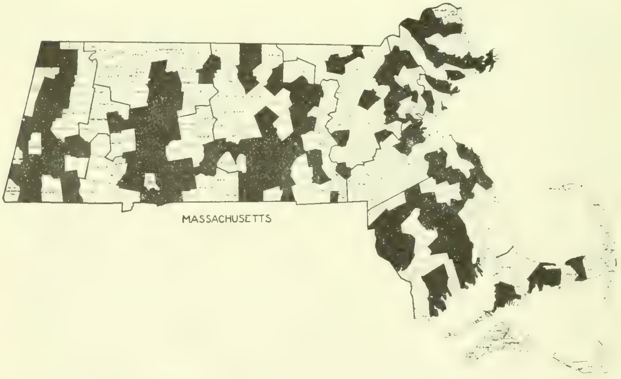

Figure 2. The Black Areas Show Geographical Distribution of Cephalosporium sp., 1935-1939.

FIELD OBSERVATIONS

Limited field observations by the writers have been supplemented by extensive field notes of trained scouts and other collaborators. During the five years 1935–1939 the Shade Tree Disease Laboratory at Massachusetts State College received approximately 7000 specimens for diagnoses. Of this number approximately 75 percent were collected from elm trees. The total number of trees found to be infected with *Cephalosporium* sp. was 501. Figure 2 shows the geographical distribution of the fungus within the state.

The disease is characterized by a gradual wilting and drying of the leaves, especially on the terminal twigs. In the summer the appearance of yellowed foliage or "flags" in the crown is usually the first sign of the presence of the disease. Later the leaves die, turn brown, and roll in from the margins toward the upper surface of the leaf. The death of the twigs is evidenced by drooping, drying out, and a tendency of the terminal leaves to persist for some time. Usually these symptoms appear first in a small section of the crown and gradually enlarge as the disease spreads from the smaller branches to the larger. The disease in Massachusetts has been found to advance progressively over a period of years. This is in agreement with Liming's statement that affected elms show an increase in the diseased condition the second year of observation. Goss and Frink (11) describe the yellowing as beginning at the base of the leaf and gradually spreading up along the midrib, then out along the veins to the margins; this being followed by the browning of the tissues and the death of the leaves from the margins inward.

---

[3] Richmond (23) proved ascigerous form of this Phomopsis to be *Diaporthe* sp.

The internal symptoms usually precede the external; a streaking of the wood in affected twigs, particularly in the spring wood, is a characteristic of the former (Fig. 3). The streaks are brown and may be more pronounced than those associated with *Ceratostomella ulmi* (Schwarz) Buisman. However, as no distinguishing characteristics for the accurate field identification of diseases affecting the vascular tissues of elms are known, only the isolation of a fungus known to be associated with the discoloration in elm wood can determine whether a fungus disease is present. In trees where the disease is well established the discoloration often forms a solid ring, but where the disease is less serious the streaking may be confined to one side of the twig or may form a discontinuous ring in the spring wood.

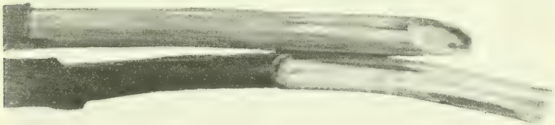

Figure 3. Diseased Elm Twigs, showing characteristic discoloration in the spring wood.

LABORATORY STUDIES

The Fungus

The morphology of the genus Cephalosporium is described by Buchanan (7) as being characterized by its well-developed hyaline mycelium and its slender, unbranched conidiophores in which nonseptate spores are abstricted from the tip. These spores are pushed to one side by the development of additional spores. The spores produced in this manner from the tip of a condiophore are stuck together by mucus and thus remain as a head.

The mycelium is much branched and septate, and is hyaline in all cases, at least when young. The sterile hyphae are of indeterminate length. The diameters of the hyphae vary from 5 to 25 microns. The cell contents, at first homogeneous, become somewhat vacuolate and later hold a large number of oil drops. The hyphae cross and recross repeatedly; they penetrate the medium to a depth of half an inch in agar. The organism grows well only in the presence of an abundance of oxygen.

The conidiophores develop abundantly on all hyphae that lie at the surface of the medium and upon the aerial hyphae when formed. A few develop even below the surface of the medium. They are slender, hyaline and vary in length from a micron or two to 20 or 30 on some aerial hyphae and 10 to 50 microns on a moist surface or in a moist atmosphere. They are usually nonseptate.

The spores are formed by the abstriction of the tip of the conidiophore. Each is enveloped in mucus, the amount depending upon the moisture of the atmosphere in which it develops. In a dry atmosphere only sufficient moisture is found to cause the spores to stick together in a head. In a moist atmosphere the globule of mucus swells until it completely envelopes the spores, and careful observation shows the spores floating free in the liquid. This liquid sometimes amounts to three or four times the mass of the spores. The heads vary in size from 10 to 35 microns and contain from two to numerous spores. The spores usually contain granules and are ovoid to cylindric with rounded ends. When the conidiophores are short, the spore masses are found upon the surface of the hyphae. Sometimes, after a conidiophore produces a head of spores, some undetermined stimulus causes it to resume growth and produce a new head. This phenomenon may occur several times, resulting in masses of spores at intervals along the conidiophores. The spores developed on the moist surface of the medium are usually larger than those of the aerial conidiophores, and frequently continue to enlarge after separation from the hyphae, becoming considerably elongated, even crescent shaped and falcate. When grown to several times their original length they become septate, from one to six or eight septa being formed. These spores then bud at one or more points and develop new conidia of a similar size and shape. In this manner large masses of allantoid, septate conidia are produced, which remain attached to each other by slender threads. Many of these spore masses in the older portion of the culture are distinctly visible to the naked eye. In an atmosphere sufficiently moist some of the erect conidiophores are found to be capped by these long septate spores rather than by the spores of the more usual short, nonseptate type. Every gradation in shape, size, and septation may be observed in a single microscopic mount from some cultures. The spores borne on aerial conidiophores and forming heads of the usual type are from 4 to 15 microns in length and one-half to one-third as broad. Those that develop in a moist atmosphere vary from 5 to 15 microns and are one-fourth to one-half as broad as long. Those that develop on the surface of the medium in the presence of an excess of moisture either resemble the preceding or become allantoid or falcate, 20 to 30 by 3 to 5 microns.

The fungus obtained by the writers, in pure culture from single-spore isolations, is characteristic of the genus Cephalosporium as described by Buchanan. It is extremely variable both in color and in texture. When first isolated from diseased wood the colony may be rich red, pink, reddish brown, orange, gray, or white. The color is due mainly to a staining of the agar by the fungus. The colony is cottony and fairly thick while the edge is characterized by feathery irregularities (Fig. 4). The transfer colonies tend to vary widely from the original colonies; some become brilliantly colored and very fluffy (Fig. 4), while many bleach out and the mycelium becomes more recumbent. The stock colonies kept many months in culture by transfers, tend to become white with some streaks of pale green or brown, recumbent mycelium, and a smooth edge; these in turn may produce brown, reddish brown, or reddish colonies with the mycelium tending to return to its original fluffiness.

The mycelium gives rise to myriads of erect conidiophores each of which bears a head of spores at its tip. To obtain spores for study a tuft of mycelium was

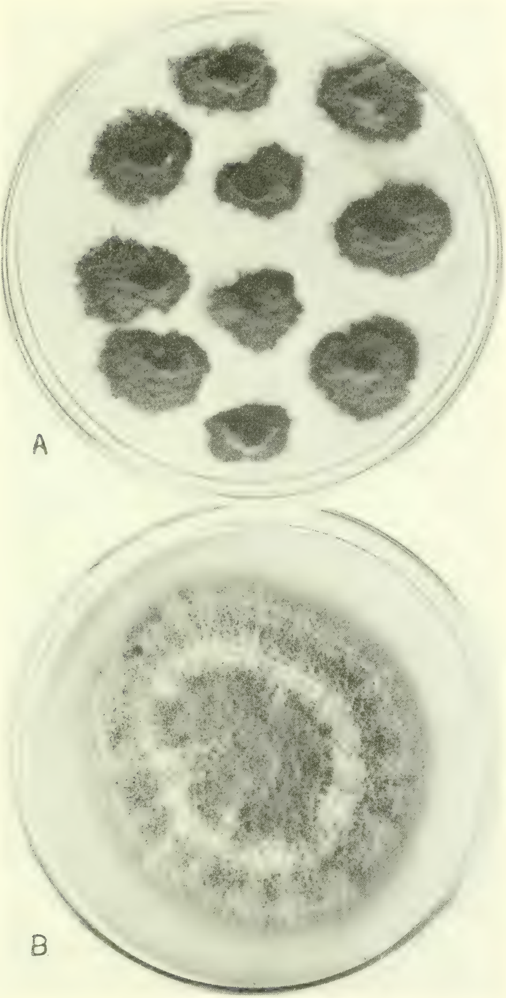

Figure 4. Cultures of Cephalosporium sp.

A. Young culture made from tissue plantings of discolored elm wood in potato dextrose agar medium. (Slightly reduced.)

B. Typical transfer culture on potato dextrose agar medium, one week old. (Slightly reduced.)

removed from the culture by means of forceps and washed in a drop of distilled water on a glass slide. The resulting spore suspension was then examined under the microscope. The spores are hyaline and vary in shape from ovoid to fusiform to allantoid (Fig. 5). They contain oil globules; the size varies from 2 to 6 microns by 6 to 20 microns with probably a small percentage either larger or smaller. The average size of spores computed from five different cultures is 4.6 by 11.4 microns.

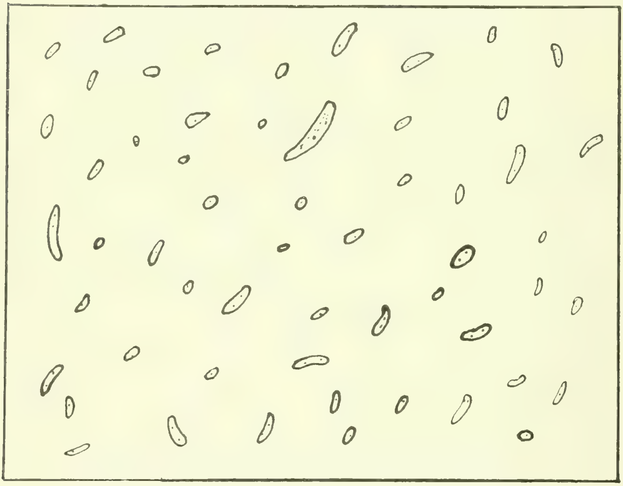

Figure 5. Conidia of the Causal Fungus of the Elm Wilt. (x 1000)

The mycelium is finely branching, hyaline, and septate; it anastomoses frequently. The branching is irregular (Fig. 7), with an angle of approximately 90° at the fork. The hyphae may be 6 microns in diameter but the terminal hyphae are smaller and more threadlike in appearance. Large spore masses similar to those described by Buchanan were found in many cultures, especially where the aerial mycelium was not abundant.

The ease with which the organism may be cultured is illustrated by an incident which occurred during the routine work in the laboratory. After tissue plantings had been made, the elm specimens, in envelopes, were placed in a wooden file until the cultures should be ready for examination. When the specimens were removed for comparison with their respective agar plates, it was found that one drawer was swollen and the specimen envelopes were decidedly moist. In three of these envelopes were twigs the tissue plantings of which showed growth of *Cephalosporium* sp. These twigs were covered with tufts of mycelium growing out through the lenticels. Cultures were made from the hyphae taken from each specimen. These cultures all yielded growth of *Cephalosporium* sp. and one twig yielded a pure culture.

The Disease

Small pieces of infected twigs showing pronounced discoloration were prepared for sectioning. The wood was first boiled in water to remove air; part of the wood was then embedded in celloidin according to Wetmore's (26) adaptation of Jeffrey's method and the rest was sectioned directly without embedding. All of the twigs were sectioned with the sliding microtome. For the purposes of the present studies, both methods of preparation were equally satisfactory. Some of the sections were stained with Haidenhain's haematoxylin and safranin. However, unstained sections not only yielded much better results, but also were simpler to prepare. Whether or not embedding of diseased twigs in celloidin and detailed staining of sections might be more valuable in studies extending over a long period of years, could not be predicted from the relatively limited observations reported here.

Fungus hyphae were found to be present in the vessels and tracheids of the

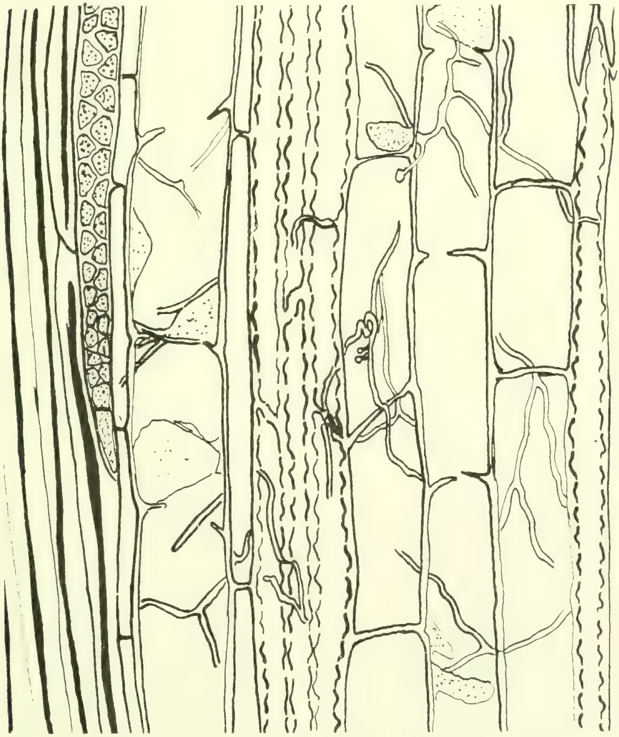

Figure 6. Longitudinal Section of Infected Elm Wood, showing fungus hyphae and tyloses in the vessels. (x 800)

discolored areas. The vessels were clogged with gummy, brown tyloses throughout the infected areas. The result of infection of the host by the fungus is, therefore, a typical vascular mycosis (Fig. 6).

With the possibility in mind that the fungus might be spread by spores within the vessels, measurements of the width of vessels and tracheids in the elm wood were made, in the early summer of 1935. It was found that in the spring wood the average width of the vessels, between the two inner walls, was 32.5 microns, while the corresponding measurement of the tracheids was 20.6 microns. These figures were computed from measurements made of 35 tracheids and 35 vessels. The widths of these elements were found to be relatively constant, so that it was not considered necessary to make a greater number of measurements. Since the average size of the spores was found to be 4.6 by 11.4 microns, the figures arrived at, together with observations of the fungus spread in experimental trees also reported in this paper, seemed to justify the supposition that the fungus might easily be spread inside the tree by means of spores.

In a paper entitled "The Distribution of Spores of Wilt-Inducing Fungi Throughout the Vascular System of the Elm by the Sap Stream," which he presented at the meetings of the American Association for the Advancement of Science in December 1936, Banfield (3) arrived at a similar conclusion after experiments regarding the spreading of spores within elms.

INFECTION EXPERIMENTS

Cultures Used

Spore suspensions were made from fungus cultures by pouring sterile water into the petri dish containing a culture and transferring the spore suspension thus formed to sterile test tubes by means of sterile pipettes. From this suspension hanging drops were prepared in sterile water and in dextrose solution; the suspension was also smeared on thin discs of potato dextrose agar in Van Tieghem cells under sterile conditions. All of these preparations were kept in sterile petri dishes with distilled water in the bottom to prevent the drying out of the media. The spores in the dextrose solution and those in the sterile water germinated in 72 hours (Fig. 7). The growth was very slow and ceased after a few days. There was no evidence of branching hyphae from these spores. On potato dextrose agar the spores produced hyphae in 24 hours, and normal branching growth followed (Fig. 7).

Spores which were incubated on agar in darkness germinated readily. Spores which were incubated on agar where it was light during the daytime, but where exposure to direct sunlight was limited to a short time each day, showed no hyphal growth during a period of two weeks. Spores which had already germinated were exposed to the above conditions at the same time, and at the end of two weeks the mycelium had grown profusely and extended to the edge of the Van Tieghem ring. The spores which had been incubated in the light for two weeks without germinating were then placed in the dark and incubated there for ten days, but no hyphal growth resulted.

In an effort to determine the thermal death-point of the spores, 5 cubic centimeter portions of the spore suspension previously described were placed in sterile test tubes and subjected to heat in water baths at various temperatures ranging from 50° to 80° C. for ten minutes each. The tubes were then cooled rapidly and the contents poured into petri dishes containing potato dextrose agar, and incubated for five days. There was a marked decrease in the percentage of spores

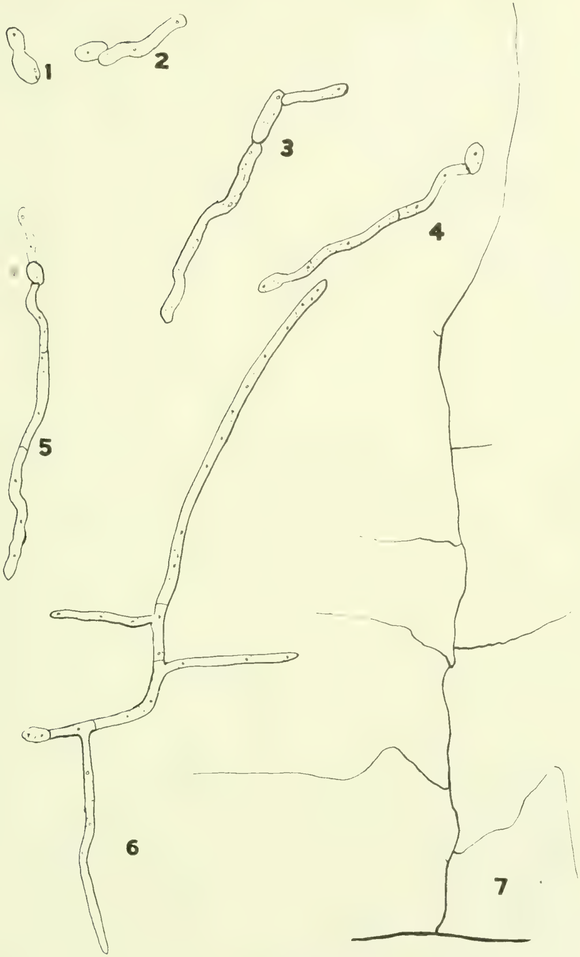

Figure 7. 1 — 5, Germinating Spores. (x 1000)
6, Germinating Spore, showing first branching. (x 1000)
7, Typical Terminal Branch of Mycelium in Cephalosporium sp.

viable after subjection to a temperature of 75° C., and no spores remained viable after subjection to 80°.

Test tubes containing 5 cubic centimeters each of spore suspension were subjected to a temperature of —20° C. for various periods of time; the suspension was then warmed rapidly, poured onto potato dextrose agar, and incubated. Spores subjected to this temperature for as long as 28 days showed no decrease in viability.

The same strain of the fungus which was used in the inoculations, to be described presently, was grown on various culture media under identical physical conditions and incubated at a temperature of 25° C., with results shown in Table 1.

TABLE 1.—GROWTH OF THE FUNGUS AS AFFECTED BY THE MEDIUM

Medium	Growth in 7 days (Inches)	Description of Growth
Potato dextrose agar	1	Cottony and white.
Potato dextrose agar with lactic acid added	¾	Cottony and white.
Nutrient agar	1	Center of colony very fluffy, edge thin and recumbent.
Prune agar	1	Recumbent.
Oatmeal agar	1	Similar to growth on prune agar.
Malt agar	7/8	Mycelium coarsely fluffy and quite sparse.
Corn meal agar	7/8	Colony definitely zoned, very sparse, with many spore masses visible to the naked eye.

The same strain was grown on potato dextrose agar at various temperatures, to determine the effect of temperature on the physical properties of the colony. Results are shown in Table 2.

TABLE 2.—GROWTH OF THE FUNGUS AS AFFECTED BY TEMPERATURE

Temperature °C.	Period of Time	Extent of Growth	Description of Growth
25–30	24 hours	1 cm.	Cultures of fungus which had been previously isolated from wood as gray cottony colonies were white and recumbent with a very even edge.
20	7 days	14 mm.	Mycelium slightly more fluffy than in cultures grown at 25°–30°.
10–15	7 days	5 mm.	Mycelium white and recumbent.

The formation of spore heads (Fig. 8) in the Van Tieghem cells, where the spores produced hyphae on potato dextrose agar, occurred within two to three days after the germination of the spores. All three types of conidiophores described by Buchanan[4] were formed. There were some aerial spore heads, some subsurface spore heads, and innumerable free-floating spores on the surface of the agar. The spore masses, of which he speaks, were not observed in these preparations, but were found in great quantity on the surface of many of the petri dish cultures; some of these masses were as large as 2 millimeters in diameter.

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[1] A brief statement of Buchanan's description is given on page 5 of this paper.

The spore heads are borne on short conidiophores from which the spores are abstricted at the tip. These spores cling together to form a head. As few as one or two spores to a head were observed in some cases, while most heads contained many spores. Some heads were highly refractive because of the large quantity of mucus. A very few conidiophores were observed which had more than one head, forming a chain of several spore heads.

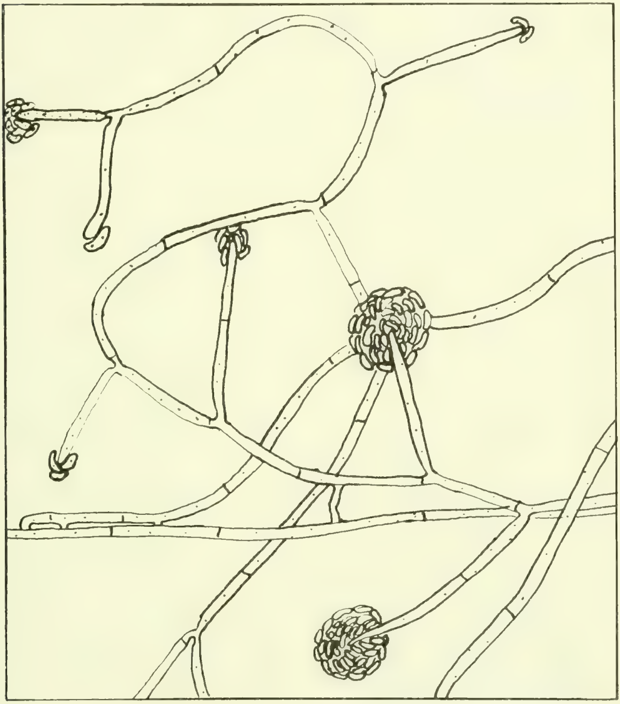

Figure 8. Mycelium Growing in Van Tieghem Cell, showing spore heads and anastomosing hyphae. (x 1000)

Methods of Inoculation with Host Reactions

For use in inoculations a culture of the fungus, as nearly typical as could be found, was selected. This culture had been obtained from twigs which had been sent to the laboratory from the town of Northbridge. The twigs had been collected by Achod Ahmadgean, July 23, 1935, from a tree situated on the East Douglas Road near the town line. The tree was described as being approximately twenty-five feet high and at that time not seriously affected by the disease.

Single-spore colonies from this culture were obtained by the streak method; i. e., a spore suspension was made in sterile water and streaked on the surface of a petri dish by means of a sterile platinum loop; any isolated colonies which resulted were then transferred to fresh petri dishes. Transfers of these cultures were made and incubated in petri dishes on potato dextrose agar and also in flasks containing elm twigs and sterile water. Twig media of each of the species and varieties of elm used in the experiments were prepared. The inoculations from twig cultures in the following experiments were made from the medium which corresponded to the tree being inoculated. The viability of the organism was

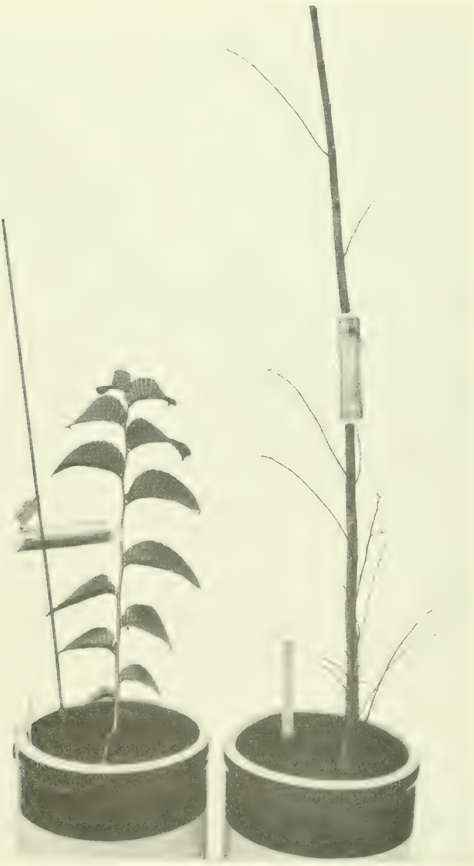

Figure 9. Trees in Greenhouse with Inoculation Cylinders, on leaf (left), and on trunk (right).

tested following recovery of the fungus in each instance by infecting additional elms from the cultures obtained.

In five experiments, young elm trees, four to six feet in height, of each of the following species and varieties were obtained from a nursery and grown in earthen crocks in the greenhouse: *Ulmus americana* L., *U. americana* L. (var. *ascendens*), *U. campestris* L., *U. glabra* L. var. *fastigiata* Rehd., *U. parvifolia* Jacq., and *U. pumila* L.

Experiment 1.

Procedure:— One tree of each of these species was inoculated, July 15, 1936, in the following manner (Fig. 9): a section of bark on the main trunk was washed with 70 percent alcohol and allowed to dry, then slit vertically with a sterile scalpel for a distance of about three centimeters. The bark was then gently loosened from the wood along each side of the cut and a small piece of bark from a twig medium on which the fungus was growing vigorously was inserted beneath the loosened bark. The wound was bound with sterile wet cotton held in place by a celluloid cylinder. The cotton was kept wet with sterilized water for about two weeks and then allowed to dry out, after which the cylinder and cotton were removed from the trees. Checks were prepared by following the above procedure except that sterile instead of fungus-laden bark was inserted into the wound.

A duplicate set of trees was inoculated, on the same day, in the manner described above, but with a slice of agar on which the fungus was growing substituted for the fungus-laden bark.

Results:— The first trees to show definite wilting were the two American elms, with perhaps a slightly quicker reaction in the tree inoculated from the twig culture than in that inoculated from the agar culture. A month after inoculation the leader of the former had died back for a distance of about 40 centimeters, the other terminal twigs showed some evidence of drying out, and the leaves had fallen from the drying twigs. At the same time the tree inoculated from the agar culture showed similar symptoms except that the leader had died back for only about 30 centimeters. No other trees in the experiment showed any symptoms at this time.

The dying back of the two American elms continued throughout the winter and on January 14, 1937, collections were made for cultural and morphological studies. On the first tree the fungus, as evidenced by streaking and growth from tissue plantings, had progressed 13 centimeters upward from the point of inoculation and 14 centimeters downward. The following spring new shoots sprouted from the base of the tree, but the trunk had died back to within 20 centimeters of the ground (Fig. 10), approximately 20 centimeters from the point of wounding and inoculation.[5] The second tree was entirely dead at the time of collection, but no streaking was evident and the fungus could not be isolated from the wood, even at the point of inoculation. It was assumed that the death of the tree was due to maladjustment to the unnatural conditions under which it was grown, and this tree was discounted in considering the results of the experiment.[6]

The two trees of *U. americana* L. (var. *ascendens*) evidenced some drying near the tip of the terminal shoots. In the tree inoculated from the twig culture the discoloration extended 3 centimeters upward and 2 centimeters downward. The fungus was reisolated from the streak. In the tree which had been inoculated from the agar culture the streaking extended 2 centimeters upward and 2 centimeters downward; the fungus was reisolated from this discoloration also.

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[5] In nature, comparable fresh injuries by insects would serve readily as infection courts if the insects themselves were the principal vectors. (Becker 5, 6.)

[6] Some of the trees received from the nursery did not grow well in the crocks, but the majority of the trees which were not used in the inoculations showed no ill effects. For this reason, it was considered a fair test to experiment with trees growing in crocks.

Neither of the English elms (*U. campestris* L.) showed any external symptoms of the disease. Only one tree, that which had been inoculated with the twig culture, showed discoloration; in this the streak extended 4 centimeters upward and 2 centimeters downward. The fungus was isolated from the tree showing discoloration but not from the one which showed no discoloration.

The specimens of Moline elm (*U. glabra* L. var. *fastigiata* Rehd.) obtained for the experiment were in very poor condition when received. Of the two inoculated, one died shortly ater the inoculation; the other, which was inoculated from the twig culture, was dead at the final inspection. It showed no extension of the discoloration, but the fungus was reisolated from the point of inoculation after a period of six months within the host. These results were not considered a fair test of the susceptibility of this host and have not been considered in the analysis of results from experimentally induced infections.

Neither of the trees of U. *parvifolia* Jacq. exhibited any external symptoms of the disease. There was no internal discoloration in the tree inoculated from the agar medium, and tissue plantings from the point of inoculation did not yield the fungus. The tree which had been inoculated from the twig culture showed discoloration 3 centimeters upward and 1 centimeter downward; the fungus was reisolated.

The Siberian elms (*U. pumila* L.) also showed no external symptoms. The tree inoculated from the twig culture showed discoloration for 4 centimeters upward and 7 centimeters downward; the tree infected from the spores in agar medium showed streaking 2 centimeters upward and 3 centimeters downward. The fungus was reisolated from both trees.

The check trees showed no symptoms of the disease.

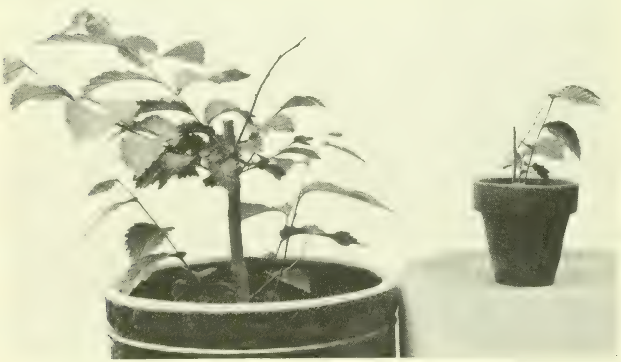

Figure 10. American Elms which died back after inoculation with the causal fungus. Cephalosporium sp. was reisolated from the pruned leaders. Photographs show new sprouts from below the infected wood.

Experiment 2.

Procedure:— One tree of each of the six varieties was inoculated, July 31, in the following manner (Fig. 9): alcohol was brushed over a leaf and allowed to evaporate; the surface of the leaf was then scratched with a sterile scalpel so as to injure the epidermal tissue, and in some places pierce the leaf; after which a suspension of spores and mycelium, prepared from an agar culture in sterile water, was poured over the leaf, with care taken that some of the liquid remained on the leaf. The leaf was then placed between pieces of wet cotton and rolled in a celluloid cylinder which was covered with newspaper, to avoid possible burning of the leaf tissue, and supported by string in such a manner that the leaf might remain as nearly as possible in a natural position. The cotton was kept moist with sterile water for two weeks, then dried out and removed.

The procedure was repeated on another leaf with the exception that the leaf was not injured. Another leaf was injured and treated in the same manner with the exception that a small block of agar on which the fungus was growing was substituted for the spore and mycelium suspension. A fourth leaf was inoculated with the agar block but was left uninjured. Careful checks with sterile water and agar respectively were employed.

Results:— The inoculated leaves fell from the trees when the cylinders were removed. Tissue plantings of the leaves were made, but with very little success, for it was impossible to free the cultures from contamination which overran the plates. The supposedly inoculated leaves were examined carefully for any discolorations which might indicate growth of the Cephalosporium fungus in the leaf tissue. All of the injured leaves showed a darkened area around the injuries, while the uninjured leaves showed no symptoms of parasitic activity. The discolored portions of the leaves were sectioned longitudinally with the freezing microtome. These sections, unstained, were carefully examined under the microscope, and it was found that in all cases the fungus had entered the leaf and was growing in the woody tissue of the veins (Fig. 11). Sections similarly prepared from leaves which had not been injured showed no localized discolorations and no fungus was found in the leaf tissue. Cross sections were also prepared from the leaf with similar results. It was found more difficult, however, to discover the fungus mycelium in a cross section of the leaf than in the longitudinal section. The mycelium did not progress as far as the twigs and therefore did not infect the rest of the tree.

Experiment 3.

Procedure:— Five seedlings of *U. americana* L. which had been collected from an area of natural seeding, were inoculated July 15, 1936, as follows: two trees were inoculated by the insertion method used in Experiment 1, with bark from an elm twig culture as the inoculum for one and a small block of agar on which the fungus was growing as the inoculum for the other. Three trees were inoculated by placing the inoculum in contact with the uninjured young green shoot and holding it in place with wet cotton supported by a celluloid cylinder. For one tree, bark from a twig culture was used as the inoculum; for the other two, the inoculum was a block of fungus-laden agar. These inoculations were kept moist for two weeks, then dried out and the cotton and cylinders removed.

Results: — The inoculated seedlings of American elm all died within five months. The fungus was reisolated from those which had been inoculated under the bark, but could not be isolated from the trees which had been exposed to infection without wounding. This again indicates the possibility of the disease being spread by insect vectors.

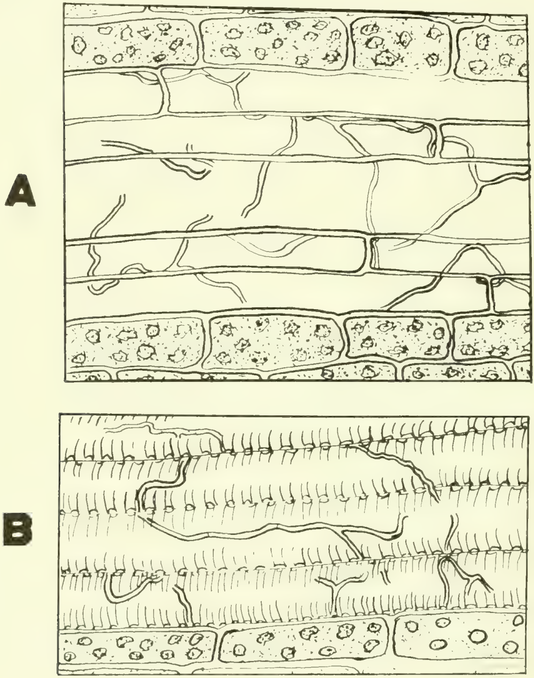

Figure 11. Longitudinal Sections of Leaf Veins, showing hyphae of the causal fungus in the xylem. (x 800)

A. Ulmus americana
B. Ulmus pumila

Experiment 4.

Procedure: — Another series of inoculations was carried out with fifteen different isolations of the fungus. These cultures were used directly from isolations without any attempt to obtain single-spore cultures. All of the cultures were less than a month old. Inoculations were made on seedlings of *U. americana* L. by the agar insertion method. Roots also were inoculated by placing a small block of fungus-laden agar on the root tissue from which the epidermis had been scraped. Following this operation the soil which had been removed from the roots was carefully replaced. These inoculations were made August 10, 1936.

Results: — Twigs from the inoculated trees, which showed symptoms of the disease, were collected December 15, 1936, and used for tissue plantings. Seven trees died back and from six of these seven the fungus was reisolated. The organism was reisolated from six more trees on April 8, 1937, giving a total of twelve successful infections out of fifteen inoculations.

Experiment 5.

Procedure: — Because of the early falling of the leaves in the first attempt to infect elms through the leaves, a second experiment was initiated, February 24, 1937, with a slightly different technique. Four young potted seedlings of *U. americana* L. were placed under a bell jar in the greenhouse; the leaves of two of the trees were injured while the leaves of the other two were left uninjured; a spore suspension was then poured over the surfaces of the leaves of all four trees with care taken that the suspension touched both the upper and under sides. Two similar seedlings were placed under a similar bell jar; the leaves of one of these were injured, sterile water was poured over the leaves of both trees, and they were used as checks. The bell jars were covered with newspaper to protect the trees from the sun. These papers were removed after two days and the bell jars were removed after ten days.

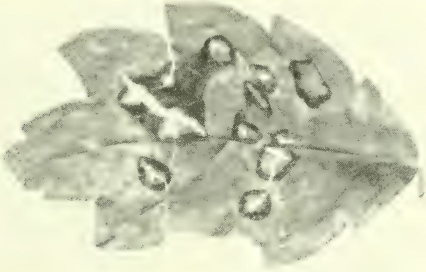

Figure 12. Infected Leaf from Elm Seedling, showing necrotic areas around inoculation wounds. (x 3)

Results: — Leaves which had been injured and inoculated soon developed necrotic areas around the wounds, which enlarged to a width of about 1.5 millimeters from the edge of the wound; the leaves then gradually became mottled and yellow. One leaf turned brown, the edges curled upward, and it finally dropped from the tree, April 12, 1937, less than two months after inoculation (Fig. 12). Another leaf, on the same date, had turned very brown from the tip to about halfway up the midrib toward the petiole; this dry part was decidedly curled and brittle, while the other half of the leaf still showed some green color. The leaf was still clinging to the tree.

The leaves which had not been injured showed no evidence of the entry of the fungus, but presented the same appearance as the two checks.

On July 9, 1937, all the seedlings were removed from the soil, the leaves removed, and the stems and roots cultured in the following manner: the seedling was immersed in 75 percent alcohol and allowed to dry under aseptic conditions; the stem was then cut into short sections which were placed in a petri dish of potato dextrose agar, and the root was similarly cut and placed in another dish. After incubation it was found that *Cephalosporium* sp. had grown from the sections of stem taken from seedlings whose leaves had been injured at the time of inoculation. The fungus was not obtained from any of the other trees.

In an attempt to discover whether or not the causal fungus will persist in an affected tree after all wood showing streaking has been pruned out, tissue plantings from the trees used in these experiments have been made in artificial media at intervals extending over a period of two years. The Cephalosporium fungus has not been isolated from any of these trees.

These results should not be confused with results of pruning following infection taking place in nature. In the latter the problem of latent infection looms large, and fresh untreated cuts or breaks may stimulate revival of the fungus.

DISCUSSION

The widespread distribution of a wilt disease of elm and possibly other trees, associated with the genus Cephalosporium, is becoming increasingly evident to those workers interested in the diseases of our principal shade and ornamental trees. The common occurrence of the fungus in diseased elms in Massachusetts indicates the importance of a thorough understanding of the problem which is raised by its very general distribution. Accordingly, an attempt has been made to discover whether or not the disease is specific to the American elm, and the entry and development of the fungus within the host has been studied.

Reisolations of the causal fungus, accomplished six months after inoculation, from the following elms — American (*Ulmus americana*), English (*U. campestris*), Chinese (*U. parvifolia*), Siberian (*U. pumila*), and the ascendens variety of the American (*U. americana* var. *ascendens*) — together with the observed entrance of the fungus into their leaves, appears to be sufficient evidence that these trees are all susceptible to the disease. The fact that the fungus does not develop as rapidly in the exotic species of elm would suggest, however, that these varieties are not so seriously affected by the disease as the common American elm and may be considered somewhat resistant.

The results obtained in the inoculations of the Siberian elms (*U. pumila*) are directly opposed to the findings of Goss and Frink in Nebraska. These workers report having inoculated eighteen trees of *U. pumila* by hypodermic injections and by stem and root incisions, with uniformly negative results. In the experiments described here, however, no difficulty was experienced in obtaining infection of two trees of this same species at the first attempt.

Goss and Frink discount the importance of leaves as a court of infection and suggest that the disease is probably spread by insects which feed on the young twigs. They found that trees which had not been injured in the leaves or twigs were infected as readily as those which had been wounded. Creager, on the other hand, finds that the leaves are the most common infection court, and that the fungus enters only through wounds. He reports having traced the fungus from the leaf through the vascular strands of the veins, midrib, and petiole into the stem.

The present experiments confirm in general the findings of Creager as opposed to those of Goss and Frink. The fungus has been found to enter the leaves and twigs when these organs are freshly wounded but not when they have been left intact or an infection court wound allowed to dry out. It has also been demonstrated that the mycelium will grow in the veins and midrib of the leaf. The progress of the fungus through the leaf into the stem followed very closely the description by Creager. Observations of hundreds of specimens received for laboratory diagnosis show that many of the elms affected by the disease have been attacked by leaf-feeding insects and bark beetles. Therefore, taking into consideration the significance of wounds in the present experiments, it would appear that insects infesting leaves or bark could transmit the causal fungus in much the same manner that the fungus associated with the Dutch elm disease is transmitted. Hence the reports by Becker (5, 6) in 1935 that *Hylurgopinus rufipes* Eich., a native elm bark beetle, invades living cambium may have particular significance in connection with the spread of the Cephalosporium fungus.

The wide variability of the cultures of *Cephalosporium* sp. which has been observed by the writers, together with the fact that both the present experiments and those of Creager have been carried out with fungi isolated in New England as opposed to the experiments by Goss and Frink with fungus cultures isolated in Nebraska, gives rise to the suggestion that the organism used by Goss and Frink may be a different strain or even a different species from those used by Creager or the writers.

The experiments conducted by the writers concerning the pathogenicity of the various strains of the fungus are indicative rather than conclusive. That the strains tested do grow in the host is evident, but to determine the relative pathogenicity of the various strains, or to separate, definitely, one strain from another, would require much more time and considerable careful study. The problem is one of great interest, but is, necessarily, outside the scope of the present study.

CONTROL MEASURES

With present knowledge, it is impossible to distinguish accurately the relative value of applied control measures, tree vigor, and what might be considered inherent resistance to the disease. Certainly some resistance might be expected in the case of a disease caused by a fungus which has been associated with the host over an exceedingly long period of years.

Not all elms affected by the disease exhibit evidence of serious damage. The presence of Cephalosporium in a vigorous tree is a condition met with rather frequently. On the other hand, the fungus is known to cause progressive death of tree parts annually and may even kill entire trees. Nevertheless, certain trees from which the causal fungus has been isolated have apparently recovered; and other trees from which the fungus has been cultured have been observed as free from disease symptoms when the trees were growing in shady places, along streams, or under favorable arboricultural conditions. Also, the progress of the disease appeared to be limited, under greenhouse conditions, in trees infected with a second wilt-inducing fungus, *Verticillium* sp., in addition to *Cephalosporium* sp., since trees infected with both of these fungi did not die back so rapidly as trees infected with either one of the fungi alone. Experiments involving inoculations of one tree with two different genera of fungi were not a part of the formal experiments previously discussed but were undertaken independently following similar observations in nature. For the most part experiments in the greenhouse on the control of this fungus and the wilt disease associated with it have been limited to the cutting out of diseased portions of trees. Similarly individuals have reported some success in treating diseased trees in the field by careful pruning, treating of wounds and scars, and judicious watering and feeding. Some trees apparently respond much more readily than others to the suggested treatment.

Individuals interested in constructive experimentation on trees affected with Cephalosporium wilt have been advised to try the following procedure:

1. Removal and burning of all dead, wind- or storm-damaged, diseased, and insect-infested parts of affected trees.
2. Sealing of all wounds with a wound paint after making a clean cut on the wood surface.
3. Spraying in order to control fungus and insect pests.
4. Watering and feeding according to apparent needs.

With due allowance for the interpretation and execution of directions, reports from individuals who have tried these suggestions indicate that treatment has achieved a measure of success. However, after so limited a time as two years, or less in some cases, it is not possible to state definitely whether more or less regular attention must be given to the building up of the general health of affected trees. The continued presence of the fungus responsible for the trouble would appear to indicate that such regular attention to tree vigor is essential for continued freedom from renewed wilt attacks. To owners of valuable trees, annual attention as a preventive is a legitimate and profitable investment if annual dividends in tree vigor and freedom from the disease are returned.

SUMMARY

1. A wilt disease of elm associated with a fungus belonging to the genus Cephalosporium Corda has become widespread in Massachusetts. The disease itself is a typical vascular mycosis which cannot be distinguished from other vascular diseases of elm, except by identification of the causal fungus from cultural studies of tissue plantings in the laboratory. Under experimental conditions, the organism frequently reacts similarly to *Ceratostomella ulmi* (Schwarz) Buisman, which causes the Dutch elm disease. Infection early in the growing season is apparently more destructive than infection late in the summer or fall.

2. The external symptoms of the disease are typical of die-back diseases, and the internal symptoms include brown streaks in the wood.

3. Aerial mycelium will grow on infected twigs under certain conditions.

4. Measurements of the spores and of vessels and tracheids, and microscopic studies of the fungus in the tissue, support the hypothesis that the fungus may be spread by means of spores within the tree.

5. Spores were found to germinate most readily on potato dextrose agar, in darkness, and in a moist atmosphere.

6. The thermal death point of the causal fungus has been placed between 75° and 80° C., and freezing was not found to exert any influence on the viability of the spores.

7. Sporogenesis is typical of the genus Cephalosporium as described by Buchanan.

8. Inoculations were made from single-spore colonies in stems and leaves of elm trees of the following species and varieties: *U. americana* L., *U. americana* L. (var. *ascendens*), *U. campestris* L., *U. glabra* L. var. *fastigiata* Rehd., *U. parvifolia* Jacq., and *U. pumila* L.

9. Infection followed inoculation of freshly wounded leaves in all cases; and all the trees, with the exception of *U. glabra* L. var. *fastigiata* Rehd., were infected by the twig inoculations in fresh wounds. In nature, comparable fresh injuries by insects would serve readily as infection courts if the insects themselves were the principal vectors; and the reports by Becker of a native elm bark beetle invading living cambium may prove to have particular significance in connection with the spread of the Cephalosporium fungus.

10. The fact that the findings of the writers agree with previous results obtained in New England and do not agree with those obtained in Nebraska, suggests the possibility that more than one strain, variety, or species of Cephalosporium may be concerned.

11. Based on the assumption that the fungus is native in the United States, control measures for the disease it causes should be directed toward maintaining the vigor of affected elms. Particular attention to the careful pruning out and burning of diseased parts of trees is desirable. Treatment of fresh wounds or scars should be directed toward avoidance of revival of latent infections.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 369 FEBRUARY, 1940

Annual Report

For the Fiscal Year Ending November 30, 1939

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION — 1939

INTRODUCTION

F. J. Sievers, Director

The State of Massachusetts is a pioneer in the inauguration of legislation for the regulation of sales of commercial fertilizers. This interest first expressed itself in an Act passed in 1869 at the instigation of the State College after, in its services to the agricultural industry, it became evident that great opportunities for misrepresentation and fraud existed in the fertilizer merchandizing methods then in operation. While this Act was intended to prevent the manufacture and sale of adulterated fertilizers, it did not carry the enforcement provision to make it effective. Later, when results from investigations conducted by the Experiment Station provided a sound basis for determining fertilizer values and requirements, additional legislation was urged by the College and in 1888 a law was enacted which, with slight modifications, is still in effect. This law provided the desired control and was recognized as sufficiently sound to give direction to similar legislation now in force in every state in the Union.

In some states, the authority for administering and enforcing this and other regulatory acts is delegated to the state department of agriculture while in others, of which Massachusetts is an illustration, this is the responsibility of the agricultural experiment station. Irrespective of which method of administration may at present be considered more desirable or effective, it is evident that the long history of investigations conducted by the experiment stations in closely related activities has contributed heavily to the intelligent interpretation of the law, a matter very essential in a just enforcement program. Massachusetts has been especially fortunate in having had agricultural regulatory services entrusted to individuals who were not only keenly concerned with serving the interests of the public but who were also sufficiently fortunate in personality to attract the cooperation necessary to develop a scientifically sound and agriculturally practical leadership.

This discussion in the 1939 Annual Report is timely because the year covered terminates almost coincidentally with the compulsory retirement date of Professor Henri D. Haskins. Professor Haskins retired on December 27, 1939, after almost fifty years of continuous service in the Experiment Station, during which he has been identified with this particular control service since its inception and in direct charge of its enforcement provisions for the major portion of the entire period of its operations.

It is not intended to evaluate the services of Professor Haskins or to evidence the high esteem in which he is held by his associates, a recognition well deserved and worthy of much more elaboration than is possible here. His exemplary administration does, however, set a standard for idealism in public service which not only warrants the enthusiastic support it has received from both farmers and fertilizer dealers but also bears direct evidence that the legal regulation of activities so closely related to agricultural practice may, for soundest interpretation and enforcement, be wisely delegated to the Agricultural Experiment Station.

DEPARTMENT OF AGRICULTURAL ECONOMICS AND FARM MANAGEMENT

A. H. Lindsey in Charge

Adjustments in Dairy Farm Organization and Practices in Massachusetts. (C. R. Creek and Emil Rauchenstein — in cooperation with the Bureau of Agricultural Economics of the United States Department of Agriculture.) Work on this project during the past year consisted of the preparation of a manuscript on the study which is now being considered by cooperating workers in the Bureau of Agricultural Economics.

In addition to the previous calculations of net returns on wholesale and retail dairy farms, normal returns were computed for the wholesale group on the basis of normal or average expenses and income for the ten-year period 1926–35. The average labor income per farm was increased for each of the five areas by which the farm records had been classified. In Berkshire County normal receipts were higher and expenses less, which increased net returns by $218. In the Connecticut Valley counties the increase was less — $122 per farm. The increase was greatest in the southeastern area where normal labor income was $298 greater per farm and was lowest for the farms in the northeastern area at $64 per farm. For individual farms the increase in returns under normal price conditions was low for specialized dairy farms and relatively high for farms with a poultry flock; but for those farms with cash crops of potatoes or apples, normal returns were lower than the actual farm income in 1937.

Combinations of farm enterprises with the dairy business were analyzed and those farms with almost one-fourth of the total receipts from the poultry flock had the lowest returns per farm. A small number of dairy and fruit farms showed the highest incomes; while dairy and cash crop (potatoes, tobacco, or onions) combinations were more profitable than the average of all farms. On those farms with income from poultry, crops, and dairy the net returns were also high with an average labor income of $956 per farm.

A comparison of all the specialized dairy farms with a similar number of the most diversified farms showed a loss of $18 per farm in labor income for the former and a gain of $802 for those farms with other enterprises than the dairy. The diversified farms were larger in total size of business, more labor was required, and this labor was more efficient than on the strictly dairy farms.

Budget analyses were made of successful dairy farms for each of the five areas to show items and amounts of receipts, expenses, and capital investment as well as the various factors of size, production, and efficiency. The same analysis was made for each of four types of enterprise combinations with the dairy business. Pasture and hay improvement practices, methods of feeding the dairy herd, crop fertilization practices, and other methods of management were discussed for each farm.

Enterprise Relationships and Farm Organization on Selected Farms in Massachusetts. (C. R. Creek and Carl Bokina.) A study was made of physical inputs and costs of producing set onions on 25 farms in the town of Hatfield for the 1938 crop year. The total costs of growing and harvesting an acre of onions averaged $267 on these farms with a total of 126 acres. Less than four acres per farm were grown on 17 farms and only two farms had 15 or more acres. Man labor averaged 509 hours per acre with a range from 371 to 667 hours. Fertilizer was applied at the rate of 2860 pounds per acre, and 29.6 bushels of onion sets were used. Man labor, which included the value of the operator's time and of family labor, accounted for 47.7 percent of all costs, while sets and fertilizer were each 18 percent.

Labor costs were analyzed by various operations and the greatest amount of work was in cultivating and weeding at an average of 187 hours per acre or 37 percent of all man-labor costs. Clipping the onions required 106 hours, and setting 97 hours per acre. Of the total man labor, 56 percent was expended before the time of harvest.

This study was published by the department in mimeographed form, entitled "Inputs and Costs of Producing Set Onions in Hatfield, Massachusetts."

Labor Saving Methods and Techniques on Vegetable Farms. (C. R. Creek and Richard Elliott.) Data were collected for this study by timing the various operations in the packing of celery on 15 market garden farms in three areas in Massachusetts. Duplicate sets of data were obtained on stripping, washing, wrapping, and packing celery on each farm.

The size of the crew working in the packing shed ranged from two to twelve persons. The number of boxes of celery (one dozen bunches) which were packed per farm ranged from 15 to 117. On two farms 13 boxes were packed per hour for each person working and on two smaller farms only 5 boxes were packed per man per hour. The other farms ranged in efficiency from 7.5 to 12 boxes per man per hour.

The number of boxes of celery which were packed depended upon the efficiency of labor, the size and quality of the celery, the arrangement of tubs and benches in the washroom, and the method of handling the celery. The greatest number of boxes was put up by crews of young men who worked rapidly for a longer time and were more dexterous, especially in wrapping. Some bunches required three or four stalks of celery instead of two on farms where dry weather or blight had affected the celery. On those farms where the benches, tubs, and tables were arranged in a row the greatest number of boxes were packed per hour and per man. On farms where extra care was taken to pack celery of high quality more people were working and the output was lower per person.

A preliminary report on this project was published in the Massachusetts Commercial Vegetable Grower for November, 1939.

Competitive Factors Influencing the Supply of Market Milk and Cream in Massachusetts. (A. A. Brown and J. E. Donley.) Milk marketing continues to command major attention. Studies in the Springfield milk shed are nearing completion. Two reports have been recently published: "Milk Cartage in the Southwick-Agawam Area of the Springfield Milk Shed," Bulletin 363; and "Product-Costs of Milk to Dealers in the Springfield Area, 1935," Bulletin 365.

The determination and appraisal of the location and characteristics of the supply within the milk shed are the current and final phases of the investigation for this market. Significant findings to date are numerous. Three might be specifically mentioned.

First, it has been found that the bulk of the dairy farmers make low average daily deliveries to the market. Analysis of 1183 records of full-time Grade B shippers showed that 21 percent had a daily average of 86 pounds (one 40-quart can) or less; and 60 percent a daily average of 172 pounds (two 40-quart cans) or less. The weighted average for the 710 shippers in the group was 103 pounds, with a total range from 17 to 1550. Using the average farm price of $2.465 per hundredweight for the milk shed, these shippers would receive a mean gross farm income from milk of $2.54 per day. The significance of a small volume of business is in no way diminished even though the maximum price applicable, the Class I price of $3.25, were used. Should the resultant amount of $3.35 be the major source of income, it would still be insufficient to satisfy dairymen. Any milk-marketing program should recognize this characteristic of production as a major premise.

A second finding of note is the relationship between volume of deliveries and seasonal variation. The relative seasonal variation between November and June was highest for small dairies. As the daily deliveries per dairy became larger, the relative seasonal variation decreased. The relationship between volume of production and seasonal variation is especially important to a program aiming at stability in a market supplied by 710 producers whose average shipments were 103 pounds per day.

The third noteworthy development was in the study of average farm prices by areas. The milkshed naturally divides itself into 14 areas within which dealers might reasonably compete for supplies or producers compete for markets. On an actual price basis, the average for each area tended to show some logical relationship to location. Three of the areas enjoying relatively high average prices were adjacent to the market; the fourth area of this group and the area with the highest average price were farthest from market. On a common fat content of 3.7, however, the area having the highest average price was adjacent to the market. With this one exception, the areas in which the higher average prices prevailed were at a distance from the market, whereas the areas with the lower average prices tended to be near it. In 8 of the 14 areas, however, the average price was within a range of one-fourth cent per quart. The relatively uniform price in these middle areas suggests a proportional distribution of the same dealers or dealers with similar operations among those areas.

The tendency for higher prices to prevail in the areas more distant from the market is probably due to the absence of competition from flat-plan dealers. The bulk of the flat-plan dealers pick up their supplies close to the market. Since they pay the Class I price for all milk but can handle only a small portion of the supply available, there is probably much unrest among the remaining producers with a strong inclination to shift dealers. Rather than bother with these shifting producers, the larger dealers move into areas too distant for the small flat-plan dealer to haul from profitably. The result of such practice is to throw the bulk of the producers in the nearby areas not using the flat-plan outlet over to use-plan dealers with low Class I utilization. The effect of such procedure would be and probably has been to create an area of constant threat to market stability. This, too, is in contrast to the prevailing notion that the potential sources of cheap milk are "up-country." In the light of these conclusions, a reappraisal of the market organization is in order.

DEPARTMENT OF AGRONOMY

Walter S. Eisenmenger in Charge

Tobacco Projects. (Walter S. Eisenmenger and Karol J. Kucinski.)

Brown Root-Rot of Tobacco. The crop preceding tobacco frequently exerts a decided influence on the yield and quality of tobacco. It seems probable that the so-called brown root-rot of tobacco may be the result of residual effects associated with the plants grown on the field the previous year. Plants with high lignin, grown on the field previously, give rise to a general soil flora different from the decomposing flora when the lignin is not there in such abundance. Although the lignin is probably not a cause of the trouble, its presence invites a foreign micro-population, thus changing the soil environment for the tobacco roots.

The plan for determining the influence of the preceding crop on tobacco was continued as in previous years, using the same crops, twenty-three in all, including cereal and forage crops, vegetables, flowers, and even weeds.

In general, the various crops ranked about as in other years in their effect on yield and quality of tobacco. However, 1939 was regarded as an unusually good tobacco year in this locality, and the differences in yield and quality of tobacco following the various crops were not so great as in 1938, which was considered a poor tobacco year.

Tobacco Grown on Old Sod. An attempt has been made to overcome the unfavorable effects on tobacco yield and quality usually witnessed when old sod is plowed under preceding a crop of tobacco.

An old timothy sod area was divided into four plots. Plot 1 was given an application of 200 pounds of nitrogen in midsummer of the year before tobacco was grown, and plowed immediately; Plot 2 received no nitrogen, but was plowed at the same time as Plot 1; Plot 3 was given the same nitrogen treatment as Plot 1, but was not plowed until the following spring; and Plot 4 received no nitrogen, but was plowed at the same time as Plot 3.

Plot 1 showed the highest yield and crop index, indicating that the addition of nitrogen to sod plowed the previous summer had caused the greatest decomposition of the ligneous materials in the sod. On the other hand, applying nitrogen the previous summer and allowing the grass to grow produced an accumulation of vegetation which only added to the supply of tissue and retarded the growth of the tobacco. There was probably more nitrogen in the vegetation and soil of this plot (3) than of Plot 4, but it was of little avail in the presence of too much tissue. Lignin is one of the last components to decompose, while ammonification and nitrification are contingent upon the first stages of decomposition.

The Use of Nitrogen as an Aid in Decomposing Old Sod. (Karol J. Kucinski and Walter S. Eisenmenger.) Calcium cyanamid at the rates of 100 and 50 pounds of nitrogen per acre was added to an old sod before it was plowed under in the fall of 1938. Another similar sod area, receiving the same fertilizer treatment, was plowed under in the spring of 1939. Although this year's growing season was exceptionally dry, thus hindering the decomposition and nitrification of the old sod, it was found that yields of potatoes, corn, and cabbage were in line with those obtained in previous years. Determination of nitrate nitrogen throughout the growing season for the past three years showed that the rate of decomposition of the old sod was faster where nitrogen was plowed under.

Although the differences in yields and chemical analyses between the respective treatments were not as great as in previous years owing to the abnormally dry growing season, yet the addition of nitrogen to old sods before they are plowed under seems to aid in their decomposition and thus lessens their usually harmful effect.

The Relative Rate of Nitrification of Nitrogen Materials on Certain Tobacco Soils. (Walter S. Eisenmenger and Julien Richard.) The purpose of this investigation was to ascertain the fate of various forms of nitrogen from different sources and to establish the length of time each form could be depended upon to furnish a supply of nitrogen to the growing tobacco plant. The materials used were urea, sulfate of ammonia, dried blood, and cottonseed meal. Addition of phosphorus increased the rate of nitrate formation. Organic matter supply was important in increasing nitrate formation. The maximum rate of nitrate formation was reached in approximately thirty-five days, and nitrification apparently stopped in fifty days. In general rate of nitrification, the several materials are ranked as follows (in decreasing order): (1) urea, (2) sulfate of ammonia, (3) dried blood, and (4) cottonseed meal.

The Absorption by Food Plants of Chemical Elements Important in Human Nutrition. (Walter S. Eisenmenger and Karol J. Kucinski.) Lettuce, cabbage, and celery were grown on soil to which the cations sodium, potassium, magnesium, and calcium were added at the rate of 500 parts per million per individual plot. The anions chlorine, sulfate, and phosphate were used on additional plots at the rate of 200 parts per million. The roots and tops of the plants were analyzed to determine the effect of these soil applications.

The results were somewhat inconsistent with those obtained in other seasons, particularly the intake of sulfur by cabbage, which showed a decrease instead of the expected increase. Whether this decrease was due to the season or to some undetermined cause is not yet apparent.

The Intake by Plants of Elements Applied to the Soil in Pairs Compared to the Intake of the Same Elements Applied Singly. (Walter S. Eisenmenger and Karol J. Kucinski.) Experience has shown that the application of cations to soil tends to increase their quantity in the plant. This is especially true of magnesium and potassium. The experiment here described was designed to determine whether, when two elements are added to the soil together, the plant will absorb less than it does when each is added singly. The materials used supplied calcium, potassium, and sodium at the rate of 250 parts per million of soil, and lithium at the rate of 100 parts per million. Lithium is exceedingly toxic; therefore it was added several months before seeding. Although the experiment is still in a preliminary stage, a lack of consistency in results is already apparent.

When lime and a potassium compound were applied together, the amount of potassium in the plant was less and the amount of calcium greater in all cases than when the respective elements were applied singly.

When lime and a sodium compound were applied together, there was less sodium in celery and in cabbage (tops) and more sodium in cabbage roots and in lettuce than when the sodium compound was applied alone; there was more calcium in celery and in lettuce and less in cabbage (whole plant) than when lime was applied alone.

When compounds of sodium and potassium were applied together, there was more potassium in celery and less in cabbage than when the potassium compound was applied alone; there was more sodium in cabbage (tops) and less in cabbage roots and in celery than when the sodium compound was applied alone.

The figures for lithium were too few to be of significance.

The Relative Intake of Certain Elements by Calciphyle Plants and Calciphobe Plants Grown on Soils at Varying pH. (Walter S. Eisenmenger and William H. Bender.) The question of the relative nutritional value of plants grown under different environmental conditions has led to a study of the intake of mineral elements by the plant, as influenced by the calcium ion and by the hydroxyl ion when both are added to the soil in the form of hydrated lime.

The intake of calcium, magnesium, nitrogen, phosphorus, potassium, and iron was observed on limed and unlimed soil with a pH of 7.3 and 4.4, respectively. The calciphyle plants were barley, sweet clover, and Kentucky bluegrass; the calciphobe plants, oats, peanuts, and redtop; and the intermediate plants, wheat, cowpeas, timothy, and tomatoes.

When lime was applied to the soil, all plants showed an increase in calcium; all plants of the intermediate class and two-thirds of the calciphobe and calciphyle plants increased in magnesium; all intermediate and calciphobe and two-thirds of the calciphyle plants increased in nitrogen. One-half of the intermediate, all of the calciphobe, and two-thirds of the calciphyle plants decreased in phosphorus as a result of liming. No relationship could be determined between intake of potassium and liming. Liming increased the iron content of 80 percent of all plants grown, from which it would seem that the assimilation of iron is not based on its solubility in the soil, for iron is more soluble in acid soils.

Since the application of lime to the soil affected the intake of other elements besides calcium, it would seem that the hydroxyl ion also has an influence on absorption by the plant.

Magnesium Requirements of Plants. (Walter S. Eisenmenger and Karol J. Kucinski.) A plot of land known to be deficient in magnesium was divided into four sections and treated as follows: no treatment, magnesium alone, magnesium plus lime, and lime alone. Eleven species of plants were planted across the sections and observations made as to the sensitivity of these plants to magnesium deficiency and the relative intake of calcium and magnesium for the different treatments.

It was found that when only magnesium was added, all plants increased in magnesium, and seven of the eleven decreased in calcium. When calcium and magnesium were added, one of the eleven plants decreased in magnesium and two in calcium. When calcium alone was added, five decreased in magnesium and three in calcium.

In general, magnesium seems to be much more easily introduced into the plant than calcium when additional amounts are added to a soil. The addition of magnesium plus calcium, on the other hand, may diminish the intake of both elements by the plant.

It was observed this year that calcium applications hastened the maturity of certain cucurbits, as canteloupes and watermelon, by about two weeks; and that those receiving lime were higher in sugar content at maturity than those not receiving lime.

The photograph on page 52 shows the marked response of celery to liming. Cabbage, on the other hand, did equally well on the limed and unlimed portions of the plot.

Investigation with Various Winter Cover Crops for Onion Fields. (Karol J. Kucinski and Walter S. Eisenmenger.) Onion growers in the Connecticut Valley do not as a rule use a winter cover crop on their onion fields. A winter cover crop of rye, which is generally used on tobacco fields in the fall, if seeded on an onion field would necessitate spring plowing. It is the practice of onion growers to plow their fields in the late fall in order to have the fields ready for onion planting in the early spring as soon as the ground is free from frost. This practice of fall plowing of onion fields is responsible for the sheet erosion and especially for the excessive dust storms which are witnessed during late fall, winter, and early spring.

It is the object of this investigation to find a winter cover crop which, if seeded in the late fall after the onion fields have been plowed, will produce a desirable cover and yet winterkill so as not to interfere with the early planting of onions.

Last year, buckwheat, spinach, barley, oats, spring wheat, and spring rye were seeded on October 19, on a plowed onion field. Results showed that this date was much too late for production of a proper cover which would prevent wind and sheet erosion. This year, the same cover crops were seeded two weeks earlier. Observations made during the middle of December show that buckwheat and spinach did not produce sufficient growth for an adequate cover, while barley, oats, spring wheat, and spring rye gave promise of a fairly good winter cover.

In the future, it may be desirable to make the seedings somewhat earlier, although with the increasing use of tractor power for plowing, the onion grower has had a tendency in the past to let his fall plowing go until a short time before the ground freezes.

Onion Breeding. (Hrant M. Yegian.) The Connecticut Valley onion growers follow the practice of planting seed sets for the production of market onions as early in the spring as it is possible to prepare a proper seed bed. If the sets could be planted in the fall, the crop could get an earlier start. During the past two seasons preliminary selection of onion plants was made for the purpose of obtaining new types that will possess the characters of high yield and winter resistance, and at the same time will be of the quality desired by the market. Some very promising types have been obtained. Seed sets from these selected types, if planted in the early part of September, will make considerable growth during fall, resume growth early in the spring, and mature good-sized bulbs at the same time as the commercial Ebenezer onions. The characters for "bolting" and winter injury due to freezing and heaving of soil, however, must be bred out and practical problems of fertilization must be solved before the fall planting of sets can be adopted by the commercial growers.

The Effect of Arsenious Oxide (As_2O_3), Arsenic Oxide (As_2O_5), and Antimony Oxide (Sb_2O_3) on Soil and Plant Growth. (Hrant M. Yegian and Walter S. Eisenmenger.) The question of whether arsenic is cumulative in the soil and may eventually become harmful to plant growth is important in areas where orchards have been sprayed over long periods or where much arsenic has been applied to lawns for parasites. Antimony was included in the study, not because of its intensive use in agriculture but simply to learn whether an element with chemical properties similar to arsenic acts in the same manner.

Greenhouse experimental evidence on the effects of arsenious, arsenic, and antimony oxides on Merrimac fine sandy loam and subsequent crop growth warrants the following statements: antimony oxide applied to a series of pots did not affect either plant growth or yields of barley and buckwheat, and the soil was not injured even temporarily by applications up to 2000 p. p. m. The pH of the soil at all concentrations was the same, and the nitrification in soil was not depressed.

Three successive pot tests were run for each of the arsenic treatments. The pH of the soil dropped from 6.1 to 5.6 with the heavier application (2000 p.p.m.) of arsenious and arsenic oxides. Arsenious oxide (2000 p.p.m.) and arsenic oxide (600 p.p.m.) did not appear to retard nitrification of cottonseed meal in soil. In the first crop test arsenic oxide, which is very soluble in water, showed a higher toxicity than arsenious oxide, which is relatively insoluble in water. The difference in toxicity of these two oxides was not so pronounced in the second run, and there was no difference in the third run. Concentration of soluble arsenic in the soil, therefore, seems to be the primary cause of arsenic toxicity. The injurious effect of arsenic is primarily on the root system of plants. Plant species, however, vary in susceptibility to arsenic toxicity; furthermore, in open-pollinated varieties there is a variation in the susceptibility of individual plants. Continuous cropping is not so effective in reducing arsenic toxicity as is the increase of organic matter of the soil. In soil, sorption of soluble arsenic takes place in the presence of organic matter. Accordingly, in addition to other soil factors, arsenic toxicity can be related to the organic matter in the soil, being high in soil deficient in organic matter and low in soil well supplied with organic matter.

Relationship of Natural Vegetation to Physico-Chemical Properties of Soils of Massachusetts. (Walter S. Eisenmenger and Walter S. Colvin.) Natural vegetation is often an index of the land's potentialities. In this study plant type was correlated with soil type, water-holding capacity of soil, and pH of soil. A total of 425 sites (uncultivated) was investigated and the following observations made.

In correlating plant types with the water-holding capacity of the soil, plants were divided into four groups: those most abundant on land with low water-holding capacity (40 to 50 percent), such as pitch pine, broom sedge, and lespedeza;

those found most abundantly on soil of medium water-holding capacity (70 to 90 percent), such as sheep laurel and black birch; those found on land with high water-holding capacity (90 to 100 percent), such as sugar maple, beech, and highbush blueberry; and finally those found with equal frequency irrespective of the water-holding capacity of the soil, such as red maple, lady's slipper, and white pine.

Plants were divided into three classes with respect to tolerance of acidity. The plants found most commonly at low pH (3.5 to 4) were such plants as low blue indigo, lupine, scrub oak, and pitch pine; at medium pH (5 to 6), gray birch, highbush blueberry, sensitive fern, alder, ironwood, meadow sweet, red cedar, and skunk cabbage; at high pH (6 to 7), such plants as ash, canoe birch, buttercup, elm, Kentucky bluegrass, sugar maple, mouse-ear chickweed, common plaintain, English plantain, strawberry, dandelion, and shrubby cinquefoil.

The writers believe that this material could be extended to serve as a guide in evaluating farm land.

Soil Conservation Research Projects. (Karol J. Kucinski and Walter S. Eisenmenger.)

A Survey of Erosion Problems Arising from Changes in Land Use. It has been shown that there were 1,400,000 bushels of potatoes grown in 1927 in Massachusetts and a yearly average of 1,975,000 bushels for 1928 through 1937. In 1938 the yield was 2,041,000 bushels and the Market Service estimates a yield of 2,324,000 bushels for 1939. Potato growers for the past several years have obtained good prices for their potatoes, thus encouraging them to expand their acreage. In Massachusetts the demand has always greatly exceeded the supply of native-grown potatoes. In some cases large out-of-state growers have come to Massachusetts in order to be close to the retail market.

No previous work has been done to acquaint one with the erosion problem arising from this increase in potato acreage. Growing of potatoes on a large scale is relatively a new venture on some of the farms in Massachusetts, especially in the western foothills and plateau. Numerous acres of old sod have been plowed under on the sloping hillsides for this purpose. As yet only slight sheet erosion is noticed on these fields probably on account of the presence of large amounts of organic matter. Great concern has been felt by some who think that, after a few years of cultivation, the organic matter now present in these new potato fields will decompose and the soil readily erode, since no cover-cropping system is practiced. It is the purpose of this investigation to determine the nature and extent of the area involved. It is of further interest to find out whether these new potato areas are of such character and so located that they would lend themselves to soil erosion if no precautionary measures are being taken by the farmer for its prevention.

An Investigation of the Source and Nature of Erosional Damage on the Alluvial Soils of Massachusetts. The object of this study was to ascertain sources and extent of the damages to the alluvial soils resulting from the periodic flood waters of the Connecticut, Merrimack, and other streams of Massachusetts.

In times of serious flood much of the land is covered with silt to depths varying from a few inches to several feet. Some of this deposit is so sandy as to be unfit for cultivation and in some cases constitutes a wind erosion hazard. In other places the material laid down contains very little sand but is high in silt and clay fractions.

A detailed study of damages to agricultural lands was made after the 1936 and 1938 floods along the Connecticut River at the Hadley, Northampton, Hatfield, Deerfield, and Northfield meadows. It was found that the land damages due to the 1936 flood were much more severe than those caused by the 1938 flood. The 1938 flood and hurricane came during and in some instances prior to the harvesting season, thus causing greater economic loss to farmers than the 1936 flood which came when no crops were in the field.

Besides mechanical and chemical tests, pot cultures have shown that fine silt deposited in Deerfield and Northfield meadows was beneficial, while the sandy deposits in Hadley and Hatfield were harmful if more than four inches in depth.

A more general reconnaissance survey of the flood damages to the soils along the Housatonic, Blackstone, Deerfield, and Merrimack was made. Particular notice was paid to the amount, type, and extent of soil damage found along these rivers. Many pictures of the soil damages were taken very soon after the flood, before man had time to obliterate the damages by plowing, scraping, or other methods. These pictures are being assembled for use as illustrative matter in a final report.

A Study of the Physical and Chemical Properties of Wind-blown Soils. In the past no one has tried to determine whether there is any relation between the physical-chemical properties of Massachusetts soils and their susceptibility to wind erosion. It has been observed that only certain types of soil in Massachusetts are affected by wind. In general these wind-blown soils are coarser in texture than those soils not subject to blowing. It is of great interest, from both the practical and academic standpoint, to find out just what the true physical-chemical properties are which control the degree of wind erosibility of a soil. It is also of interest to discern which of these various physical-chemical properties of a soil are subject to the control of man and just what changes take place in the soil complex when one or more of these physical-chemical properties are changed by man's management or by natural influences.

Soils from wind-eroded and non-wind-eroded areas are being examined for their physical and chemical properties, such as mineral and organic colloidal fractions, plasticity, hygroscopiscity, mechanical analysis, heat of wetting, heat conductivity, capacity of absorption, and such other soil properties as are deemed of value.

Various ions and cations are being added in different rates to the soil to establish their effects on the physical and chemical properties of wind-eroded soil. A wind tunnel is being developed and these soils will be subjected to its influence in order to find the relative effects of the various ion and cation treatments on the wind erosibility of the soils.

The Relation between the Rate of Wind Erosion and the Principal Factors Affecting it. Wind erosion, although not the most important, is perhaps the most evident type of soil erosion that is found in the Connecticut River Valley and on Cape Cod.

The dust storms which occur in the Connecticut River Valley prevail mostly on onion and other vegetable fields during the fall and again in the spring when the ground thaws, then dries, and is swept off by the northwesterly winds. Besides the damage to the field and the young vegetable crops, the dust storms are a nuisance to the people living in the Valley. A detailed survey of the Connecticut River Valley has been made in order to determine the extent of land affected. Observations have been made on the soil type and soil characteristics which have a bearing on the problem of wind erosion. It has been found that in certain cases where severe wind erosion is now prevalent, the fertility of the soil is so low that there is some question whether the area should ever have been plowed for intensive cultivation.

From the standpoint of agriculture, the sand dune area of the Cape does not present a serious problem. The dust storm areas are found along the northern and southern shores and the tip of the Cape. Most of these areas are used for summer resorts and recreation. State agencies have initiated various experimental measures to control the shifting of the sand dunes. It has been found that sod plantation of hog cranberry, beach grass, poverty grass, sand pea, Scotch broom, and blueberry are very effective in stabilizing active sand dunes. Various pine trees, such as *Pinus sylvestris, P. Mughus, P. austriaca* and *P. rigida*, have also been used very effectively in establishing permanent cover on the dunes.

Podzols of Massachusetts. (Arthur B. Beaumont.) Most of the soils of Massachusetts belong under the category of brown podzolic. However, there are two areas in the State where well-developed podzols are found. These areas are at opposite ends of the State and at extremes of elevation—on the Berkshire Plateau at elevations above 2000 feet and on Cape Cod at elevations of 50 to 100 feet, above sea level. There is little difference in mean annual rainfall, which is about 44 inches. Berkshire podzols have been developed from soils of medium base status under a cover of conifers, mainly spruce and northern hardwoods; Cape Cod podzols under a cover of pines, which is now principally pitch pine (*Pinus rigida*). Below is a brief description of profiles of podzols from the two areas:

	Berkshire Podzol (Becket fine sandy loam)			*Cape Cod Podzol* (Hinckley coarse sand)		
			pH			pH
A_1	0—3″	black humus	3.3	0— 4″	black humus	3.70
A_2	3— 8″	purplish gray	3.4	4—30″	gray	4.30
B_1	8—12″	dark, reddish brown, friable (orterde)	4.1	30—32″	black, hard ppt. humus	4.80
B_2	12—18″	yellowish brown	4.4	32—36″	coffee brown hardpan (ortstein)	4.65
C	18″—	yellow till	4.5	36″—	pale yellow sand and gravel	4.95

Sunflowers and Their Possibilities. (Karol J. Kucinski and Walter S. Eisenmenger.) There is a long-felt need among farmers in the Connecticut Valley for a new crop which can be grown successfully on lands which are being taken out of tobacco or onion production. Although it is known that the country's demand for sunflower seed is greater than the present supply, no information is available concerning the possibilities of sunflowers as an economic crop in Massachusetts. The farmer growing sunflowers would readily find channels for marketing his seed to poultrymen of this region, while the stalk has possibilities as ensilage material for cattle feed.

This experiment was undertaken to determine the rate of seeding, fertilizer requirements, date of seeding, and yields of seed and stalk obtainable when sunflowers are grown under conditions prevalent in Massachusetts.

It is concluded that any land suitable for corn production will also be suited for growing sunflowers. Since the sunflower plant can withstand more cold than corn it can be planted somewhat earlier. Early seeding of sunflowers produced nearly a ton of seed per acre. Seedings of one seed per hill every 18 inches in 36-inch rows proved to be better than 2 plants per hill in 36-inch check rows. Plants seeded closer than 18 inches apart had a tendency to be thin and weak, causing lodging after storms. When sunflower plants were used for silage it was found that yields as high as 19 tons per acre were obtainable. Cattle that were fed sunflower silage seemed to relish and thrive on it.

The results obtained so far with growing of sunflowers have been very encouraging and further investigation of a more detailed nature should be made to determine the feasibility of growing sunflowers economically in Massachusetts.

Trials of Thirteen Different Hay Seeding Mixtures. (Ralph W. Donaldson, W. G. Colby, and Karol J. Kucinski.) Data obtained at the conclusion of four seasons' harvest of two cuttings per year of various hay seeding mixtures indicate the following: (1) A number of mixtures containing varying proportions of alfalfa showed slight but not significant differences in yield. One containing 50 percent alfalfa (seeded) ranked high in yield — not excelled by straight alfalfa. One mixture containing no alfalfa produced a significantly low yield. (2) Orchard grass in mixtures, while yielding comparatively well, was overmature when cutting was delayed for alfalfa blossom. Timothy seemed more desirable. (3) The average annual yield of hay was 500 pounds less from a 13-pound seeding rate than from either 17 pounds or 21 pounds. (4) A significant response occurred from muriate of potash, 250 pounds topdressed annually on half of each plot. Increased yield of hay due to potash amounted to 1½ tons, or 50 percent increase, the third season; and 2 tons, or 100 percent increase, the fourth season. The final disappearance of alfalfa on the area receiving no potash, with a good stand remaining on the treated area, apparently accounts for this difference. (See photograph on page 52.)

Pasture Investigations. (W. G. Colby.) In Massachusetts there are four principal factors which govern pasture production. They are in the order of their importance as follows: (1) Soil fertility, (2) grazing management technique, (3) species and species strains, and (4) climate.

High quality pasture herbage is probably the most profitable crop which can be produced in Massachusetts, but this is true only when the cultural requirements of this crop are given the same consideration which is now given to other valuable crops grown in the State. Failure to recognize this fact in the past is largely responsible for the present very poor condition of our pastures. It must be recognized that before desirable pasture species can produce large quantities of palatable, nutritious herbage, the soil must be able to supply them with adequate quantities of all plant food nutrients. The general level of soil fertility must be relatively high. Although the practices which may be necessary to maintain a high level of soil fertility in pasture sods may differ from those followed with other crops and may also differ from one section to another, the principle of maintaining an adequate level of soil fertility as a prerequisite to satisfactory herbage production, applies universally.

As pastures become more productive as a result of improved soil fertility relationships and the presence of heavier-producing species, grazing management technique becomes increasingly important. Such practices as rotational grazing, the omission of early spring and late fall grazing, the clipping of undergrazed areas and the spreading of droppings are all practices which are not only beneficial but in many cases essential to the maintenance of high productivity levels.

By directly exercising a considerable degree of control over the first three factors which govern pasture production, the adverse effects of the fourth factor, climate, are greatly reduced.

Permanent Pastures. Pasture areas which have never, or only infrequently, been tilled and seeded are included in this category. Ten years' experience with fertilizer topdressing experiments on permanent pasture sods in Massachusetts has shown that, although the composition of the vegetation can be greatly improved and a marked increase in production effected, it is not possible in the great majority of cases to develop and maintain a first-rate pasture by the use of topdressing materials alone. The explanation may be found by examining existing natural soil fertility relationships. The natural level of soil fertility in most Massachusetts pastures is very low, and topdressing applications of fertilizers alone do not raise this level sufficiently high to encourage the establishment and growth of the more productive, desirable pasture species.

Semi-permanent Pastures. This includes those plowable areas which are tilled, fertilized, and seeded to a pasture mixture once every 3 to 6 years. Pastures of this type have given very satisfactory results in Massachusetts and the acreage of such pastures is increasing rapidly. The success of semi-permanent pastures may be largely explained on the following basis:

1. Tillage of the soil, accompanied by adequate fertilization improves the soil's physical condition and raises the level of soil fertility to such a point that nutritious and productive pasture species are able to establish themselves and remain productive for several years.
2. The use of a seeding mixture has permitted the introduction of desirable, high-yielding pasture species which not only increase the total production of pasture herbage but also aid in maintaining a more uniform production of herbage throughout the pasture season.
3. The importance of desirable grazing management practices has been frequently demonstrated on pastures of this type with the result that grazing management technique, in general, is given careful consideration. This favors a more uniform production of a high quality herbage throughout the grazing season and aids in prolonging the life of the seeding.

COOPERATIVE TOBACCO INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture in Cooperation with the Massachusetts Agricultural Experiment Station

C. V. Kightlinger, U. S. D. A., in Charge

Black Root-Rot. (C. V. Kightlinger.) This project, to develop new strains of Havana Seed tobacco which will be highly resistant to black root-rot and acceptable for type and quality of tobacco and producing capacity under Connecticut Valley conditions, is being continued.

Havana Seed 211 is the most acceptable of the new strains of tobacco which have been developed and tested thoroughly in the course of the project so far. It is grown commercially in considerable amounts each year in the Connecticut Valley, and is bought and used in like amounts each year by most of the dealers and manufacturers who deal in and use Connecticut Valley tobacco. It comes near to fulfilling the principal objectives of the project, but it needs some improvement in minor characteristics. Selections within the strain are being made and tested each year, in an attempt to improve the strain in this respect.

New strains are also being produced by crossing the most acceptable selections of Havana Seed 211 and highly approved strains of regular Havana Seed, and selections from the progeny of these crosses and their backcrosses are being made and tested, to provide new material for use in the project, in case the selections of Havana Seed 211 do not possess all the improvements that may be desired.

Overwintering of Common Tobacco Mosaic Virus in Soil under Natural Conditions. (C. V. Kightlinger.) One purpose of this project was to ascertain whether common tobacco mosaic virus contained in plant material could overwinter in soil under natural conditions in the Connecticut Valley, and if so, to what extent the virus overwintered in such manner might constitute a source of inoculum for infections of mosaic in succeeding crops of tobacco, under the conditions of the experiment. Another purpose was to ascertain to what extent mosaic inoculum might be disseminated from diseased to nondiseased tobacco plants by means of ordinary cultural practices.

The land used in working the project had not grown any Solanaceous crops and had not had any refuse material of such crops placed upon it for more than ten years previous to its use for this purpose. Five plots in all were used. One plot, separated from the others by approximately one hundred feet of turf land, was used to grow tobacco for control purposes during the course of the project. Of the four other plots, two were kept fallow, and two were planted to tobacco the first year, whereas all four plots were planted to tobacco the second year, in accordance with plans for the experiment. One plot was used the first year to grow tobacco which was inoculated artificially and completely with mosaic virus as soon as possible after planting, in order to permit the disease to become fully systemic, to provide suitable material for study of the first objective of the project. This plot from which the tobacco was cut and removed and one of the fallow plots on which this same tobacco was placed, were plowed at once and then again the next spring, and were used the second year to grow tobacco for the further study of the first objective. As a result, there were provided for this purpose the second year, one plot which contained only the stumps and roots of systemically diseased plants, and one plot which contained only the tops of the same tobacco. One other plot was used the first year to grow tobacco which had five percent of its plants inoculated artificially with mosaic virus as soon as possible after planting, to provide a suitable setup for the study of the second objective, which was made the first year. However, because of the prevalence of mosaic which developed in this tobacco the first year, this plot from which the tobacco was cut and removed and one of the fallow plots on which the same tobacco was placed were plowed at once and then again the next spring, and were used the second year to supplement the study of the first objective of the project.

One strain of Havana Seed tobacco was used for all purposes of the experiment. All the tobacco received like treatments, except for the special treatments which have been explained.

At the time of plowing for tobacco the second year, samples of upturned stumps and roots and of the upturned tops of the systemically diseased tobacco plants, were taken to determine whether this overwintered tobacco material contained virus capable of infecting greenhouse tobacco plants. Duplicate tests using ten plants each were made for each kind of material collected. All the plants inoculated by hand with water extractions of this material developed mosaic, while duplicate controls consisting of ten plants each developed no mosaic when treated to the same inoculating technique except that sterile water was used instead of water extractions of the upturned tobacco material.

In field tests made the third year of the experiment to ascertain to what extent the mosaic virus overwintered in such manner in soil might constitute a source of inoculum for mosaic in the second succeeding crop of tobacco, special care was taken not to let any cultivating tools touch the plants and possibly thereby disseminate inoculum from plant to plant. And when the tobacco had grown so large that no further cultivating could be done without brushing the plants, counts of the mosaic-diseased plants were made, and were assumed to represent the extent to which the overwintered mosaic virus had served as a source of inoculum in this case. This assumption seemed to be justifiable, inasmuch as the control tobacco which had been cultivated and treated in like manner had developed no mosaic.

In the case of the tobacco grown on the plots where only systemically mosaic-diseased tobacco had been grown the previous year, it was found that out of 1894 plants grown on the plot which contained only the stumps and roots of the preceding tobacco, 16, or .84 of one percent of all the plants, had developed mosaic; and out of 1125 plants grown on the plot which contained only the tops of the preceding tobacco, 9, or .80 of one percent of all the plants, had mosaic. And in the case of the tobacco grown on the plots where the previous crop of tobacco had been completely but probably not all systemically infected with mosaic, it was found that out of 2129 plants grown on the plot which contained only the roots of the preceding tobacco, 12, or .61 of one percent of all the plants, had developed mosaic; and out of 1232 plants grown on the plot which contained only the tops of the preceding tobacco, 10, or .81 of one percent of all the plants, had mosaic.

In the tobacco grown for use in ascertaining the extent to which mosaic inoculum might be disseminated from diseased to nondiseased tobacco plants by means of cultural practices, 5 percent of all the plants were inoculated artificially by hand, but otherwise the tobacco was treated as tobacco grown for commercial purposes would ordinarily be treated. Counts of mosaic-diseased plants were made just before topping and just before harvest. From counts made just before topping it was found that out of 2122 plants grown on the plot, 191 or approximately 9 percent of the plants had developed mosaic, or 4 percent more than the number of plants which had been inoculated artificially by hand. Counts made just before harvest showed all the plants to have mosaic.

The tobacco grown for control purposes and used for control in connection with both experiments described above, had no mosaic-diseased plants.

DEPARTMENT OF ANIMAL HUSBANDRY

Victor A. Rice in Charge

The Effect of Feeding a Vitamin A Concentrate on Growth and Reproduction in Dairy Cattle. (J. G. Archibald and C. H. Parsons.) This project has been completed and the results have been published in Bulletin 357.

The Effect of Complex Mineral and Vitamin Mixtures on Milk Production, General Health, and Reproductive Efficiency in Dairy Cattle. (J. G. Archibald.) The data have been correlated and summarized, and preliminary reports have been prepared on two of the three long-time feeding trials conducted under this project. Data from the third trial are in process of correlation and summary. Results from the two studies which have been completed do not show any benefits from the feeding of the two proprietary mixtures in question.

A Study of the Mineral Elements of Cows' Milk. (J. G. Archibald and C. H. Parsons.) Supplemental iron in the form of iron ammonium citrate, fed to a group of eight cows in the college herd during the winter of 1938–39 did not increase the average iron content of their milk. In fact the tendency was towards a decrease. Large variations were noted in the iron content of the milk between individual cows at any given time, or between samples from the same cow at monthly intervals. Both of these types of variation were noted irrespective of whether supplemental iron was being fed or not. The iron content of most of the samples was of the order of 0.5 mg. per kilogram of milk or less, although there were a few samples where it ran as high as 1.0 mg. per kilo, or even higher.

Some dissatisfaction was experienced with the method used for determining iron and certain refinements and modifications were introduced which gave more uniform values for the samples obtained in the latter part of the season. Because of this and also because the trend toward a decrease in the iron content of the milk when additional iron was fed does not seem logical, it has been decided to repeat the work during the barn-feeding season of 1939–40. Somewhat larger amounts of supplemental iron are being fed this year.

Investigation of the Merits of Legume and Grass Silage for Massachusetts Agriculture. (J. G. Archibald and C. H. Parsons.) Results from this project to the end of 1938 together with findings of other workers applicable to conditions here, have been published in Bulletin 362. Results secured since the bulletin was issued deal chiefly with the use of phosphoric acid as a preservative for grass silage. While it would be unfair to draw final conclusions from one season's work, feeding trials with 28 cows conducted in the winter of 1938-39 indicated that:

1. The phosphoric acid silage was not as palatable to the cows and did not produce quite as much milk as either corn silage or molasses silage. Gains in weight also were less than on either of the other kinds.
2. Phosphoric acid seems to do a better job of preservation than molasses, as the carotene content of silage made with it was somewhat higher than that for a similar lot of molasses silage.
3. Flavor of the milk from cows receiving phosphoric acid silage was pronounced, by impartial flavor experts, superior to the flavor of milk from the same cows when they received either corn or molasses silage.

Approximately 125 tons of phosphoric acid silage has been stored this year, and is now being compared with corn silage in an extensive feeding trial to see whether the results of last year will be confirmed. Approximately 63 tons of molasses silage stored this year will be fed to growing dairy heifers in comparative trials with corn silage.

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

Iodine in the Ration with Reference to the Coli-acidophilus Ratio in the Stools of White Rats. (James E. Fuller and W. B. Esselen, Jr.) It is recognized that an adequate amount of iodine in food is necessary for the proper nutrition of man and animals. Food materials produced in many localities are deficient in iodine, and this fact has encouraged research workers to investigate methods for increasing the iodine content of food substances. This research suggested the study of the possible effect of increased iodine in food on the intestinal flora of white rats, with special reference to the relative numbers of *Escherichia* (*Bacillus*) *coli* and *Lactobacillus acidophilus*. This is of interest because *L. acidophilus* is considered by many to be desirable in the intestine, and *E. coli* relatively undesirable.

One group of young white rats was given hamburg steak for a month to increase the coli content of the stools, and another group of an equal number of rats was given a cereal diet to increase the acidophilus content. Then each group was divided into four sub-groups and fed as follows: 1, raw milk; 2, raw milk with added iodine; 3, pasteurized milk; and 4, pasteurized milk with added iodine. For several weeks the different milk rations were added to the hamburg and cereal diets respectively, and then for the final several weeks milk alone was given. The amount of iodine used daily for each rat represented what would be a high-iodine ration for humans if it were fed to them in the same proportion in relation to body weight as to the rats. Bacteriological tests made frequently during the course of the experiment showed that total bacteria counts were quite erratic both in individual rats from time to time, and in rats of the same subgroup at any given examination time. There was no evidence that the iodine in the ration either increased or decreased the coli or acidophilus counts, and these counts were quite as erratic as were the total counts. The experiment indicated that iodine in a quantity desirable from a nutritional or a physiological standpoint would not influence intestinal bacteria significantly.

Indol Production by Escherichia Coli. (James E. Fuller.) The theory of autointoxication is based upon the production, by bacteria in the intestine, of substances which are absorbed into the body and there cause some poisoning effect. Indol is one of these substances, and it is produced by the colon bacillus which is common in the human intestine. It is known that when plenty of sugar is available for the bacteria, little or no indol is produced. This is especially true when the sugar is dextrose, the form to which all starch and sugar in food is digested in the intestine. Studies were made in culture media on factors that might influence indol production by the colon bacillus. Results: 1, All common sugars (dextrose, lactose, maltose, sucrose), starch, and dextrine checked indol production. 2, Control of intestinal acidity by calcium carbonate or dipotassium phosphate did not check indol production. 3, Acidity did not check indol production unless the acid was concentrated enough to interfere with growth of bacteria. 4, Bile and bile salts did not interfere with production of indol. 5, When *Aerobacter aerogenes* was grown with *Escherichia coli* in a medium containing one-half of one percent of dextrose, the combined cultures appeared to use the dextrose so that the production of indol by the colon bacillus proceeded as if no dextrose had been present. The study on indol production is being continued.

The Influence of Bacteria on the Oxidation of Ascorbic Acid. (W. B. Esselen, Jr., and James E. Fuller.) This study has been completed and published in two journal articles: *Journal of Bacteriology* 37:501-521, 1939 (Contribution No. 319); and *Food Research* 4:329-334, 1939 (Contribution No. 326).

Relationship of Onion Juice to Bacterial Growth. (James E. Fuller and Ernest R. Higgins.) For many years the belief has persisted that onions and garlic have the power to prevent bacterial growth. Some success has been reported in the use of garlic to prevent spoilage of pickles, and even from the use of garlic in the treatment of tuberculosis. More recently papers have been published reporting the ability of onion and garlic vapors to prevent bacterial growth. The present study was made to determine the value, if any, of onions to control bacterial growth in pickles and relishes. The effect of onion juice in culture media was studied with several species of bacteria, with results as follows: (1) *Aerobacter aerogenes* was entirely resistant to the juice, and (2) *Escherichia coli* was nearly so. (3) *Salmonella schottmulleri*, (4) *Pseudomonas pyocyanea*, and (5) *Staphylococcus aureus* did not grow in concentrations much above 50 percent of juice, but the bacteria were not killed. (6) *Proteus vulgaris* and (7) bacteria of the *Bacillus subtilis* group grew only in low concentrations of juice, and in the more concentrated juice the bacteria were killed. The first four species are human intestinal bacteria; the fifth is from the skin, and can cause food poisoning; the sixth is common in putrefying substances; the seventh is from dust and soil. Live steam weakened the bacteria-controlling property of the juice as compared with sterilization by filtration, and steam-pressure sterilization practically destroyed the property. The juice still could hinder bacterial growth even though experiments showed that the vapors were no longer potent.

Studies of Cocci from Swimming-Pool Water. (James E. Fuller and R. H. Guiberson.) Cocci are significant in swimming-pool water because those from the nose and throat can cause infections in pool users, while those from the intestine are less dangerous and probably entirely harmless. When cocci are isolated from swimming-pool water, it is important that they be identified as intestinal or non-intestinal. As a beginning of a study of identification methods, a group of cocci identified as intestinal by commonly used methods were studied further. It was found that a pH value of 10.7 and 15 percent common salt in the medium, respectively, in place of pH 9.6 and 6.5 percent salt commonly used, made it possible to separate the cocci studied into two fairly distinct groups. The study is being continued.

Streptococci in Swimming-Pool Water. (Ralph L. France.) Results obtained in this study indicate that the "streptococci" isolated from the water in the college pool came from the body surfaces of the swimmers, and are not of intestinal origin. Further, the evidence indicates that while the bacteria appear as "streptococci" in the prelininary isolation media, biochemical and morphological tests identify the majority as micrococci. Their public health significance remains at present an unknown quantity.

Further biochemical tests will be made on these organisms, particularly their salt tolerance, chlorine tolerance, and ability to grow in a medium with a high alkaline reaction.

Co-operative Study of Milk Plating Methods with the Food and Drug Division of the State Board of Health. (Ralph L. France.) A comparative study of media and methods for plating market milk is being made with the Food and Drug Division.

Laboratory Service. (Ralph L. France.) Following is a list of the types and numbers of examinations made during the past year.

Milk (bacteria counts)	893
Ice cream (bacteria counts)	120
Water	123
Miscellaneous:	
Streptococci	2
Throat swabs	25
Paper	8
Ice	16
Total	1,187

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Effect of Soil Temperature on Gardenia. (L. H. Jones.) Low soil temperatures induce a chlorosis of gardenia. A more intense form of the malady was associated with a high level of soil nitrogen. Tests with diphenylamine on the almost white leaves gave a strong positive reaction for nitrates, indicating the inability of the leaves to utilize the nitrogen.

In order to demonstrate that the effect of soil temperature on plants in the long hot days of summer is similar to the effect obtained in late autumn, winter, and early spring, a summer series of gardenia plants was set up in the soil temperature apparatus. Chlorosis was obtained at the lower soil temperatures of 55° and 60° F. There was an absence of chlorosis at 65° F. and above. Associated with the appearance of chlorosis was the setting of a great many flower buds, most of them developing into good flowers. Although some growth took place at the lower temperatures, it was very slow. There was no bud set at 65° F. and also very little growth. With the soil temperature at 90° F., the growth was very rapid, with large leaves and no bud set.

It is thus apparent that soil temperature is a factor that not only controls the color of gardenia plants, but also affects the physiological functions of vegetative and flowering phases. The fact that chlorosis appears during the shorter days of the year should not lead to the belief that lack of light is the responsible factor. Any correlation that exists between length of day and chlorosis of gardenia is apparent only when it is considered that length of day plays a considerable role in the maximum effect that air temperature has on soil temperature.

Some attention has been given to the theory that soil temperature is not in itself a direct factor, but is a governing agent that controls other factors. Spraying chlorotic leaves with an iron solution (5 percent ferrous sulfate) has produced spotted leaves with irregular areas of dark green surrounded by the general chlorotic field. This would indicate that soil temperature either alters the absorption of iron or affects the root system so that, even if the iron is absorbed, it cannot be translocated to the leaves. There is also the fact that growth can be not only slowed down, but actually stopped by low soil temperatures. There is, therefore, cumulative evidence that nutrient absorption and nutrient translocation, either or both, may be governed by soil temperature.

Root Temperature Effects in a Nutrient Solution. (L. H. Jones and G. E. O'Brien. Cooperative with Chemistry.) Soybean plants of the Manchu variety were grown in three-salt nutrient solutions maintained at the three thermostatically controlled temperatures of 50°, 70°, and 90° F. Since the air temperature about the plants was the same, the differences in the amount of water transpired and nitrogen absorbed were due to the root temperature environment.

The results showed that the quick lowering of the root temperature from about 70° to 50° F. caused the plants to wilt. Transpiration and nitrate absorption were lowest at 50° F. The figures on nitrate absorption indicated that the optimum root temperature was 70° F. or higher, but less than 90° F. No relationship could be established between the amount of water transpired and the amount of nitrogen absorbed. It is evident that the availability of water as influenced by root temperature can alter the rate of transpiration, a factor which is independent of the evaporating power of the air. The investigation confirms other reports that the amount of solutes, in this case nitrogen, enters the plant independently of the amount of water transpired.

Plant Containers. (L. H. Jones.) Fuchsia and heliotrope have proved to be excellent plants as indicators in various types of plant containers. Fuchsia has a characteristic red midvein when nitrogen deficient. When nitrogen is applied, the first noticeable response is the disappearance of the red vein. This has taken place in a time period of 6 days. It may be detected more readily than a change in the greening of yellow-green leaves. Heliotrope in porous clay flower pots develops a matted root system against the wall of the flower pot as shown in the photograph on page 51. Since this response is due to the accumulation of nutrients in this region, the thickness of the mat indicates the zones of fertility in the soil. This mat of roots also may be used to demonstrate the necessity of keeping the pot wall moist in order to protect these feeding roots from drought.

Study of Diseases of Ornamental Herbaceous Plants Caused by Soil-Infesting Organisms, with Particular Attention to Control Measures. (W. L. Doran.) Damping-off was well controlled by subirrigation, when the pots or flats of soil, after seeding, were set in shallow pans of solutions until the soil was saturated. Results were better with vinegar or formaldehyde (1.5 quarts or 3 to 4 teaspoonfuls, respectively, per gallon) than with formic acid or pyroligneous acid as used. If soil is too wet before treatment, formaldehyde is to be preferred to vinegar, as it is also with very small seeds which may be injured by the growth of mold on the soil following the use of vinegar. With these exceptions, vinegar gave as good control as did formaldehyde. Formaldehyde, thus applied, was more effective in soils which, before treatment, were not more than 25 percent saturated than in soils which were already 50 percent saturated. It may take longer, however, to subirrigate a completely dry soil, and there was injury to some species by 4 cc. formaldehyde in such soil.

Soil in metal flats with double bottoms, the upper one perforated, was watered from below, with solutions introduced between the bottoms and thus beneath the soil, after seeding. Damping-off was satisfactorily controlled by as little as 2, or even 1 teaspoonful formaldehyde per gallon of water, with some chemical injury in a too dry soil from 4 or even 3 teaspoonfuls.

As little as one teaspoonful formaldehyde per quart of water per square foot, applied from above and worked into soil before seeding, controlled damping -off.

In applications up to those heavy enough to cause chemical injury, damping-off was not controlled by urea, thiourea, diacetone and sulfamic acid. Results were more encouraging with oxyquinoline sulfate and salicylanilide and their use is being further investigated.

Damping-off and Growth of Seedlings and Cuttings of Woody Plants as Affected by Soil Treatments and Modifications of Environment. (W. L. Doran.) Sand, sand-peat, and sandy soil were compared as rooting media for cuttings of sixteen species. Nine rooted best in soil, six in sand-peat, and only one in sand.

Cuttings of *Cornus florida* L., *Syringa vulgaris* L., *Viburnum Carlesii* Hemsl., *Prunus maritima* Marsh., and *P. subhirtella* Miq. all rooted better if taken in June than if taken later in the summer.

Indolebutyric acid was more effective than indoleacetic acid in improving rooting of cuttings of the seven species with which both were used. All treatments referred to below were with solutions of indolebutyric acid and were for 18 to 24 hours at 18° to 20° C.

Rooting of cuttings of five species was, however, more improved by solutions at initial temperatures of 30° to 35° C. (soon falling to 20° C.) than at an initial and approximately constant temperature of 20° C. Treatment at initial temperatures of 40° C. or higher was injurious.

Dilutions of indolebutyric acid (mg. per liter) which most improved rooting of summer cuttings of the following deciduous species (and of holly and hemlock) and late-fall cuttings of the conifers were: 12.5 mg. for Japanese quince and flowering dogwood; 25 mg. for lilac, Wistaria, American holly, and *Viburnum Carlesii*; 50 mg. for common hemlock, arbor-vitae, four species of Rhododendron, and *Cotoneaster horizontalis* Decne.; 100 mg. for Irish juniper, two species of Chamaecyparis, and two varieties of Norway spruce.

A delayed treatment of cuttings of incense cedar with indolebutyric acid, which was applied fifteen months after cuttings were taken, was very effective in improving rooting.

Treatments effective with softwood cuttings did not affect the rooting of hardwood, winter cuttings of four out of five deciduous species.

Damping-off of seedlings of Carolina hemlock, *Hovenia dulcis* Thunb., and *Stewartia pentagyna* L'Hérit. was not well controlled by seed treatment with red copper oxide.

Carnation Blight Caused by Alternaria dianthi S. & H. (E. F. Guba, Waltham.) Some features of this project are awaiting further field study before publication is attempted. Meanwhile, extensive breeding is in progress in an effort to obtain suitable varieties resistant to Alternaria blight and especially branch rot, caused by *Fusarium dianthi* Prill. & Delacr., a serious parallel carnation disease problem. The work is being carried on in cooperation with the New England Carnation Growers Association and Prof. Harold E. White.

Chemical Soil Surface Treatments in Hotbeds for Controlling Damping-off of Early Forcing Vegetables. (W. L. Doran and E. F. Guba, Waltham.) Treatments were applied to the surface of the soil immediately before or after seeding and the results were the same.

Damping-off was well controlled by 2 cc. formaldehyde (in 1 quart water) per square foot of soil. There was no chemical injury when 4 cc. was similarly used but control was good with 3 or even 2 cc. There was good control by 3 cc. whether soil, before treatment, was dry or up to 50 percent saturated. Control was as good when solutions were applied at 10° C. as when they were applied at 55° or 60° C.

A solution containing 4 teaspoonfuls formaldehyde per gallon of water was applied to a row 5 inches wide, immediately after seeds (of sweet peas) were sown. Final stands were much improved by 1 quart of this solution for each 2, 3, or 4 linear feet of row, with best results when 1 quart was applied to 3 feet (cr 1 gallon, containing 4 teaspoonfuls formaldehyde, to 12 feet of row).

Vinegar 215 cc. per square foot prevented damping-off without injury. There was, however, injury to some species when 235 cc. was used.

A 1-400 solution of commercial formaldehyde applied at the rate of 1 gallon to 5 square feet of seedbed or 1.89 cc. of formaldehyde per square foot has proved most useful in the control of damping-off of certain vegetables. The solution is applied after the seed is covered with soil. This treatment has not been injurious to the following vegetables: beet, celery, chicory, cucumber, eggplant, endive, lettuce, Romaine, onion, pepper, spinach, tomato, and Swiss chard. The best stands of crucifers have been obtained from the treatment of the seeds with zinc oxide. Lettuce and Romaine frequently have done better with a 1-500 solution of formaldehyde (1.51 cc. per square foot) and with the red copper oxide seed treatment. The use of lukewarm water in making the formaldehyde solution is desirable as a precaution against injury. This method of treating seedbeds to control damping-off is considered an improvement over the addition of formaldehyde dust to the soil before seeding, or over the so-called improved or direct method of adding 6 cc. of formaldehyde per square foot of bed and resting the soil before seeding. This method and dilution (1.89 cc. of formaldehyde per square foot) is safer and more practical in controlling damping-off of the Pythium type.

Control of Greenhouse Vegetable Diseases. (E. F. Guba, Waltham.) It has been conservatively estimated that about 555 tons of greenhouse tomatoes are lost to production in Massachusetts each year as the result of the tomato leaf mold disease, caused by the fungus *Cladosporium fulvum* Cke. The new Bay State tomato, resistant to the disease (see previous report), has been released for commercial production and has proved highly acceptable. Bay State is characteristically Waltham Forcing but earlier and with rather freely branching or racemose fruiting clusters, both features being derived from *Lycopersicon pimpinellifolium*, one of the original parents and the source of resistance to the disease. Since the original crosses in 1933, desirable fruit size and quality have been added to Bay State by three subsequent crosses with Waltham Forcing. The resistance of Bay State to this serious tomato disease has revived interest in the growing of greenhouse tomatoes for the autumn and winter market and incidentally will reduce substantially the cost of greenhouse management especially required in the growing of other varieties of tomatoes.

Causes and Control of Decay of Winter Squash in Storage. (E. F. Guba, Waltham.) The past season has been most favorable for high yields of squash and good keeping. Only occasional occurrences of black rot, caused by *Mycosphaerella citrullina* (Smith) Gross., and bacterial wilt rot, caused by *Bacillus tracheiphilus* EFS., and rare instances of blue mold rot, caused by *Penicillium* sp., have been noted. It has been determined that shrinkage from moisture loss in storage, from harvest to February 1, is approximately 10 percent of the weight at harvest. In the 1938–39 storage season the amount of shrinkage varied but slightly under different humidity and temperature conditions. In the 1937–38 storage season shrinkage was reduced from 9.2 percent to 7.3 percent when average mean relative humidities of 62 percent and 84 percent and average mean temperatures of 57.3° F. and 45° F. respectively were contrasted; but under low temperature and high humidity the loss from decay was approximately doubled. Decay under low temperature and high relative humidity storage conditions rises rapidly after the first of January.

Factors Affecting Yield of Onions and their Shrinkage in Storage. (C. J. Gilgut and W. G. Colby. Cooperative with Agronomy.) Twenty-five lots of onion sets gathered from a number of Connecticut Valley onion growers were grown under the same conditions on a plot of typical onion land to determine the effect on yield and shrinkage in storage of (1) variety and source of seed sets, (2) stage of maturity at time of harvest, and (3) methods of harvesting, curing, and storing. The following conclusions are based on observations made during the growing season and on experimental data thus far collected.

Although, at the time of planting, no visible difference in the quality and uniformity of the different lots of sets on trial was apparent, there was considerable variation in performance. Locally grown Japanese seed sets grew more vigorously throughout the season and significantly outyielded Japanese seed sets shipped into Massachusetts.

Onions harvested after nearly all tops had broken over yielded 30 percent more than onions harvested ten days earlier when approximately 75 percent of the tops were down. In the case of the Connecticut globe type seed sets, later harvesting resulted not only in greatly increased yields, but also in improved quality because of fewer small, objectionable bottle-neck bulbs.

Shrinkage resulting from disease after 75 days in storage ranged from 2 percent in some varieties to as much as 30 percent in others. The average for all varieties indicates that onions harvested when the tops were completely down developed 15 percent more disease in storage than onions harvested 10 days earlier, but this was more than offset by the increased yield. Onions which remained in burlap bags in the field until October 1 before being moved into storage showed approximately 5 percent greater loss from disease than onions placed in storage a few days after harvest.

The bulk of loss due to disease was caused by bacterial soft rot and Fusarium bottom rot. At the end of 75 days in storage, the former accounted for 46 percent of the decayed onions; the latter for 48 percent. Bacterial soft rot was more prevalent in the early part of the storage period than other types of decay, but decreased in amount as the storage period progressed. Fusarium bottom rot, on the contrary, was less prevalent during the earlier part of the storage period than during the latter.

It is interesting to note that while Botrytis neck rot is said to be one of the chief causes of loss in storage, thus far this season only one onion out of 2½ tons examined was affected by this disease.

Miscellaneous Tests and Experiments. (E. F. Guba and C. J. Gilgut, Waltham.)

1. *Apple Scab Control.* The apple spraying experiments were intended to determine the relation of sulfur particle size to scab control. The wettable sulfurs were all used on the same sulfur basis by weight.

Six applications were made. All treatments except that at the pink bud stage were combined with lead arsenate, and for the curculio and maggot sprays 4 pounds of lead to 100 gallons of spray were used. There were no significant contrasts in the control of scab in spite of differences in sulfur particle size. Where lime-sulfur was used in the precover sprays the usual injury, dwarfing and scant foliage, developed. The excellent control of scab with insignificant amounts of wettable sulfurs emphasizes the importance of proper timing and thorough spraying rather than the material used. When the fruit was examined for apple scab, a record of injury by the plum curculio was also made and the results show that bentonite sulfur, as represented by Kolofog, which provided the heaviest deposit and the most persistent adherence of residue, gave the best control of the curculio.

2. *Copper Sprays for Vegetables.* The cucumber plots were destroyed by mosaic before there were any appearances of downy mildew. Some rows remained green longer than others but the untreated plot outyielded all others. Higher yields were not necessarily associated with low percentages of mosaic cucumbers. With melon, downy mildew appeared late and in spite of the disease the highest yield was obtained from the unsprayed row. Drought conditions were unfavorable for tomato foliage diseases; nevertheless, there were wide differences in yield among the different treatments. With celery, 67.4 percent of the leaflets in the unsprayed rows were affected with late blight, as compared to less than 1 percent in the sprayed rows.

Diseases of Trees in Massachusetts. (M. A. McKenzie and A. Vincent Osmun.)

The Dutch Elm Disease Problem. In view of the imminence of the Dutch elm disease, which has increased in 1939 with the steady encroachment of the disease to a point in New York less than five miles from the southwestern border of Massachusetts, studies of tree diseases in the field and in the laboratory have accorded special attention to those diseases of elms which superficially are not to be distinguished from the Dutch elm disease.

Present studies of the spread of the Dutch elm disease in the United States indicate new locations for the causal fungus in parts of the States of New York, Connecticut, Pennsylvania, and Maryland in Eastern United States; and at stations in Ohio and Indiana in the Midwest. Connecticut, with 348 affected trees reported for the year, remained the only New England State in which the Dutch elm disease is known to occur. Since the first discovery of the disease in America, approximately 57,000 trees have been removed in the United States because they were afflicted with the pestilence, and about 4,109,300 additional undesirable or dead elms have been removed from zones immediately surrounding infestations. The 1939 figures for the entire country show a decrease of 40 percent in the number of diseased trees as compared with 1938. From the standpoint of Massachusetts, however, the proximity of the disease is particularly disconcerting in spite of the decrease in the number of diseased trees.

Interested agencies, groups, and individuals, including the Federal Bureau of Entomology and Plant Quarantine, the Massachusetts Forest and Park Association, arboriculturists, employees in other State and Municipal departments, and private citizens have supplemented the work of this organized project in collecting specimens from trees showing symptoms resembling those of the Dutch elm disease. On two occasions during the summer, the elms in Berkshire County were the subject of intensive scouting by trained scouts from this Laboratory. Samples of trees suspected of harboring the disease were collected also in Hampden, Hampshire, and parts of Franklin and Worcester Counties. Up to the present time (November 28, 1939) the Dutch elm disease has not been found in Massachusetts. All reports that the disease was present in the State have been investigated and found to be without basis in fact.

Considerable confusion exists as to what constitutes the Dutch elm disease. Any accurate statement relative to the occurrence of the disease must include the laboratory report of cultural isolation of the causal fungus from affected trees. Because of the close association of certain carrier insects with the spread of the causal fungus and the control measures directed against them, statements concerning these insects have sometimes been misinterpreted as relating to the fungus disease itself. It must be understood clearly that no population of carrier insects, however large, can initiate the Dutch elm disease independently of the causal fungus, *Ceratostomella ulmi* (Schwarz) Buisman. Of course, if the fungus is accessible to a large population of carriers, the spread of infection associated with the disease may be facilitated greatly. Therefore, control of the carriers is essential to any program directed against the spread of the fungus, and the 67 W. P. A. municipal tree projects in operation throughout Massachusetts during the past year had as one objective the curtailment of carrier populations which infest dead and weakened trees or parts of trees. Such programs should prove of considerable value against the day when the Dutch elm disease may be found in Massachusetts. In view of the widespread distribution of the oldest known American infestation of the imported smaller European elm bark beetle carrier in eastern Massachusetts, and the more limited infestation in Berkshire County, Massachusetts faces a serious Dutch elm disease problem on the western as well as the eastern front, even though the disease is not now known to be in the State.

Other Tree Problems. Sixty-eight fungus diseases of thirty-three hosts, including eleven diseases of elm, were identified from specimens received for diagnosis during the year.

The Cephalosporium wilt disease of elm has been found to be rather widespread in Massachusetts and has been the subject of field and laboratory investigations over a period of several years. Results have been published in Bulletin 368.

A serious fungus disease of the London Plane-tree, an exotic, hybrid, ornamental sycamore widely planted in parts of eastern United States, has been reported as causing serious damage in New Jersey and certain other locations outside of New England. Numerous inquiries relative to this disease have been received during the year, but thus far the disease has not been found upon the sycamores in New England, although the native sycamore is supposedly susceptible to infection by the causal fungus, *Ceratostomella* sp. Sycamores in this section are subject to the Sycamore Blight, caused by *Gnomonia veneta* (Sacc. and Speg.) Kleb., which commonly affects leaves and twigs. Possibly the recently reported disease, which kills the trees, in part at least, by the growth of a canker, may escape early detection because the public has become accustomed to seeing leaves wither in association with the common blight.

Winter injury was a common cause of tree disorder this year. Deciduous plants as well as evergreens suffered severely from this trouble in addition to serious secondary injury from the effects of the hurricane of September 1938. Injuries traceable to the hurricane continue to be sources of numerous inquiries. In order to facilitate the handling of these inquiries, a series of ten brief circulars has been prepared to supplement the general information on the repair of hurricane damaged trees included in Extension Circular 30. Also, at the request of the Massachusetts Tree Wardens' and Town Foresters' Association, a report on the hurricane in Massachusetts was prepared for their publication, "Proceedings of the Twenty-eighth Annual Meeting, February 8 and 9, 1939."

Crown Rot of Dogwood. (C. J. Gilgut.) This disease, caused by *Phytophthora cactorum* (L. & C.) Schroet., is serious to ornamental flowering dogwoods and is present in Massachusetts. The organism kills the bark at the base of the tree, thus girdling it and causing its death. A number of chemicals were determined to be toxic to the organism growing on artificial media. Materials which proved toxic are a solution of methyl alcohol and resin, equal weights of each, Bordeaux paint, aqueous solution of mercuric bichloride 1 to 1000, saturated alcoholic solution of mercuric bichloride, turpentine, malachite green 1 to 1000, copper sulfate solutions 1 to 10 and 1 to 100, Semesan 1 to 1000, and a saturated solution of potassium permanganate. Materials which proved nontoxic are pentachlorophenol 1 to 1000, oxyquinoline sulfate 1 to 1000, malachite green 1 to 10,000, methyl alcohol, linseed oil, and shellac. Potassium permanganate solutions at 1 to 1000 and 1 to 100 seemed to have a stimulating rather than a toxic effect.

DEPARTMENT OF CHEMISTRY

W. S. Ritchie in Charge

Cooperative Analytical Service. (The Department.)

Off-Flavored Eggs. Normal fresh eggs and those having a strong, "fishy" or "sulfury" odor were sent in by the Poultry Department of the College for examination. Chemical analyses have failed thus far to show fundamental differences in composition sufficient to account for the offensive odor.

Insecticides and Fungicides. Various samples of flotation sulfur sent in for examination were evaluated by a 300-mesh screen test and the character of the residue. The samples varied from .07 to 4.06 in percentage of material that would not pass a 300-mesh sieve.

Roach Powder. A sample was analyzed qualitatively for active ingredient and filler. The sample apparently contained sodium fluoride, a starch product, and a water-insoluble coloring material.

Lubricating Oil. Samples of new and used automobile lubricating oils were submitted for analysis. The used oils were from cars and trucks equipped with filters and represented various mileage. After extensive use these oils had "picked up" considerable carbon, gasoline, and mineral matter and their effect on density, volatility reaction, flash and fire points, and ash was considered a measure of contamination.

Some changes in the oils as a result of long-continued use were (1) increased volatility (0.39 to 3.36 percent); (2) lowered flash point (442° to 265° F.); and (3) increased ash content (0 to 0.38 percent).

The used oils were treated with eight different clarifying agents and filtered. Activated charcoal yielded a bright clear product superior in appearance to the original unused oil. Bentonite also proved efficient but had less decolorizing action.

Testing Analytical Methods. (The Department.)

Determination of Zinc in Foodstuffs. Work on the dithizone-carbamate method for the determination of zinc in foodstuffs has been continued during the past season with satisfactory results. The original "two step" method, published in 1938, has been improved by incorporating a preliminary treatment with dithizone in an ammonical solution for the removal of nonreacting bases and acids and by other minor changes to insure a more definite procedure. The use of wax-coated bottles has reduced the contamination of the reagents but some of the synthetic resins may prove more durable.

Two samples, polished rice and seed rye, together with granulated zinc for the standard were furnished various analysts under the auspices of the A.O.A.C. for collaborative work. As a whole the technique was acquired more readily than was expected, but adequate control was lacking in some instances due to inexperience. Personal differences in reading a visual color comparator lead to the belief that some of the new instruments employing a barrier-layer type of photoelectric cell would be preferable.

Determination of Boron. The investigation of dark centers in rutabagas necessitated a continued study of the Dodd method for boron. While this eventually gave concordant results, some modifications were necessary. Other methods are now being studied with a view to securing a simpler process and one less difficult to control.

The Iron, Copper, Zinc, and Iodine Content of Fruits and Vegetables Used as Human Food. (E. B. Holland, W. S. Ritchie, and C. P. Jones.) As in previous years various samples (21) of human and cattle foods have been collected and their analysis is well under way. They include cereals, processed human foods, proprietary foods, vegetables, dried citrus pulp, and young succulent grasses and clovers.

Dark Centers in Rutabagas. An experiment was conducted with two varieties of rutabagas, American Purple Top and White Cape, in four counties of the State during 1938 to note the effect of borax in preventing dark centers. The extremely wet season may have vitiated the results to some extent, but samples from treated plots showed nearly twice as much boron as from the untreated. Hollow heart, however, was more noticeable than dark centers, which had been characteristic in previous years. No samples showing the disorder were available this season.

Chemical Changes in Cooking of Vegetables. (M. E. Freeman and W. S. Ritchie.) Since mealy potatoes are more desirable in most American retail markets, attempts have been made to ascertain the chemical or physical properties of cooked potato flesh that are causally related to this character. Previous workers have observed that in mealy potatoes the cells separate to a greater extent and the moisture content is usually lower.

The fact that the cells of mealy potato tissue separate readily suggested that the pectic materials binding the cells together would be more easily disintegrated and dissolved in mealy potatoes than in waxy potatoes. The careful fractionation and isolation of the pectins in 20 samples (8 varieties) varying widely in texture did not, however, indicate a significant difference between mealy and waxy potatoes. While cooking brought about rapid changes in the pectic material, the extent of these changes as measured by the extraction of pectin did not distinguish the mealy from waxy potatoes.

Additional information concerning some characteristic properties of potato pectin was obtained. In the preparation of samples for pectin analyses, a mild heat treatment designed to inactivate the destructive enzymes was found to alter the pectin fractions. Rapid drying of sliced potatoes in a current of warm air was superior. In potatoes the three pectin fractions generally described for plant material were not clearly defined. The data led to the suggestion that potato pectin can be adequately defined by two fractions: (1) a fraction soluble in ammonium salts but insoluble in hot water; (2) a fraction easily dispersed by hot water but not by cold water. Further details of this investigation have been submitted for publication in *Food Research* under the title "Pectins and the Texture of Cooked Potatoes."

A number of investigators have attempted to correlate mealiness with low moisture content, high dry matter content, and/or high starch content. While the majority admit that there is probably a fairly high correlation, there are other conclusions to the contrary. About 200 tubers (7 varieties) were individually tested for mealiness and analyzed for moisture. The moisture contents ranged continuously from 87.4 to 69.1 percent; consequently the three classes of high, intermediate, and low moisture had to be arbitrarily defined. Three degrees of mealiness, high, medium, and low, were independently estimated. When the data were tabulated under these two classifications, it became apparent that there was a high degree of correlation between low moisture content and mealiness in these potatoes.

However, waxy potatoes cannot be made mealy simply by expelling more water by prolonged cooking. There appear to be unknown factors influencing the relative ability of tubers to retain moisture during the cooking process.

Three methods for determining the water-binding properties of starch, raw potatoes, and baked potatoes have been tested. The Dumanski method, if carefully followed, was found to be rapid and accurate for starch and other materials that do not contain water-soluble solids. The method could not be applied to raw or cooked potato tissue with much success. The dilatometric method was long and tedious and quite unreliable unless the last traces of dissolved air were removed from the sample by vacuum during a long process of intermittent freezing and thawing. The calorimetric method proved to be rapid and reliable with all types of potato material. The results of these methods agree very closely when applied to starch and raw potato pulp.

Starches from seven varieties of potatoes varying in mealiness all adsorbed about .3 gram of bound water per gram of dry material. Analyses of a few varieties of potatoes (raw) yielded a similar value. No significant differences were found between mealy and waxy varieties. Studies are now being made on baked potato tissue under these experimental conditions.

Other methods are being applied that may give additional information regarding the moisture relationship in raw and cooked potatoes.

Continuing the work reported earlier with peas, spinach samples were obtained to determine the changes, if any, due to storage and cooking after preservation by canning and freezing.

The fresh spinach was sent to the laboratory where it was dried at low temperatures as a control sample. Additional spinach from the same field was canned and frozen and so stored for three, six, nine, and twelve months. At the end of each of these storage periods three cans of spinach were opened and drained. Half the sample was dried without cooking. The other half was cooked in half of the liquor from the cans and then filtered and dried. The unused half of the liquor was kept as one sample and the filtrate from the cooking process was a second sample. The same procedure was followed with the frozen samples. Frozen spinach (one and one-half packages) was dried immediately after thawing. A second sample of one and one-half packages was thawed and cooked with a definite volume of distilled water after which it was dried. This cooking water was saved for comparison with the liquor samples described above. These were analyzed for total solids, ash and nitrogen. The samples of dried spinach were subjected to methods of proximate analysis and the methods proposed by Horwitt, Cowgill and Mendel.

In general, results obtained by proximate analysis do not show any outstanding changes. The ash in all stored samples was somewhat lower than in the original sample. It has been suggested that perhaps the blanching process removed some of the ash before the samples were processed. Long standing in the cans apparently softened the tissue, with the result that ash was removed more easily in cooking liquors. The protein was consistently higher in the cooked samples and perhaps represents a real difference. The material soluble in ether increased in the canned spinach while the frozen samples showed no change. Crude fiber apparently did not change significantly in either canned or frozen samples when stored.

It appears that changes, if any, in the spinach, when stored either frozen or canned, are not apparent by such a method of analysis.

A second method of analysis has been suggested by Horwitt, Cowgill and Mendel, which considers the solubility of food constituents using H_2O, N/10 HCl, 0.50 percent Na_2CO_3, N/10 HCl+pepsin, and 0.50 percent Na_2CO_3+ trypsin as solvents.

The water-soluble nitrogen showed no significant change as a result of storage. The values for the frozen samples were higher than those for the canned samples, indicating possibly a rupture of the cells and therefore greater extraction. Both the cooked, frozen, and canned samples had lower results with the water extraction, probably due to heat coagulation of the protein and in the canned samples a loss from the liquor.

The enzymatic digestion using HCl and pepsin showed no effect resulting from the continued storage period. In fact, all pairs (cooked and raw) were in very good agreement.

In vitro digestion using Na_2CO_3 + trypsin showed no real differences but indicated that 76.5 percent of the protein was digested regardless of length of storage or method of preservation.

In both cases, the insoluble ash and the insoluble residue were higher in the cooked than in the raw samples regardless of the time of storage. If solubility means availability there is more of these in the raw samples than in the cooked.

This work is now complete for a sample high in starch, one high in protein, and one high in roughage. These results will be evaluated as a whole before further work is attempted.

Investigations of Some Physical and Chemical Properties of Mosaic Viruses. (M. E. Freeman.) The investigations on potato mosaic under this project can be carried out only during the fall and winter months. Because of delays occasioned by hurricane damage in the fall of 1938, no experiments were attempted during the winter of 1938-1939.

Lignin and its Relation to the Absorption of Minerals by Plants. (Emmett Bennett.) The chemistry of lignin is being studied to determine its role in plant metabolism, to ascertain possible relationships with other plant products, and to understand the properties which make it possible for this substance to function as it does in the soil.

Lignin was isolated from corn cobs by an alkali method. The purified product was electrodialyzed in a Mattson cell. A partial study was then made of the solvate obtained by dispersing lignin in a solution of sodium hydroxide. Electrometric titration of the solvate with hydrochloric acid yielded data which produced a symmetrical curve with two inflection points. The first point came at about pH 9 and the second at about pH 5. Precipitation occurred and seemed complete at pH 5 ± 0.1.

Lignin dispersed in a solution of equal parts of alcohol and acetone and titrated in the same way behaved differently. The addition of lignin alone to this solution lowered the pH to a point below which precipitation occurred in the previous solution. Precipitation did not occur upon lowering the pH to 2.5.

These data indicate that lignin prepared in the manner described may differ from humates in the soil in at least two ways: (1) Neither charge nor hydration appears to be the stability factor; (2) Solvation does not occur at a pH below the precipitation zone.

Lignin appears to be different from other incrusting materials such as hemicellulose in that these substances usually have the two stability factors, charge and hydration.

Precursors of lignin. The work discussed in the last report has been written up and two papers have been submitted for publication.

The Digestibility of Lignin. Previous work with rats showed a high percentage recovery of lignin and indicated a decrease in the digestibility of nitrogen. In 1939 the digestibility of lignin and the effect of a diet of high lignin content on the digestibility of nitrogen was determined.

Rats were fed a complete diet containing 15 percent of lignin which had been isolated from corn cobs. An average of 93 ± 3 percent of the lignin was recovered.

The average digestion coefficient for nitrogen was 90 ± 3.5 in the control diet and 82 ± 2 in the lignin diet.

These data indicate that lignin is not only practically indigestible but that it may affect the digestion of nitrogen.

Effect of Storage and Processing on Carbohydrates of Some Varieties of Edible Onions. (Emmett Bennett.) The work of the project was continued as outlined with the exception that the use of "seed" (Yellow Globe Danvers) onions was discontinued.

"Set" (Ebenezer) onions were stored (A) in a warm room, (B) in a basement, and (C) in a commercial storage from November 15 to February 27. Storage A represented relatively high temperatures and low relative humidity; C, relatively low temperatures and high relative humidity; and B, conditions intermediate between A and C. The temperature and relative humidity were recorded regularly. Representative samples were obtained for analysis before and after storage.

The following results were obtained from the crop of 1938. The onions from storages A, B, and C shrunk 19, 10, and 10 percent respectively and yielded 29, 62, and 87 percent of marketable onions. The shrinkage was caused principally by respiration; apparent rotting was negligible in all cases. The sprouts represented 69, 37, and 12 percent respectively.

The dry matter of the fresh onions contained 59 percent sugars, of which 28 percent was reducing sugars and 72 percent was sucrose. During storage in B and C this proportion changed to 49 percent of reducing sugars and 51 percent of sucrose; and in A, to 34 percent of reducing sugars and 66 percent of sucrose. This change was accompanied by a loss of total sugars, averaging about 15 percent, with a minimum of about 11 percent in storage B and C, and a maximum of 24 percent in storage A. In general, the amount of total sugars lost by respiration determined the amount of shrinkage during storage. The weight of fresh onions which contained an amount of total sugars equal to the loss during storage in B and C was found to be practically equivalent to the weight of onions which was lost by shrinkage. This relationship was not true in storage A.

Sucrose appeared to be the reserve carbohydrate. In storages B and C the rate of respiration was sufficiently slow to allow reducing sugars to accumulate at the expense of sucrose. In A, however, the rate of respiration was so rapid that glucose was oxidized as rapidly as formed.

While the sugar changes noted in the onions from storages B and C were almost identical, the percentage loss from sprouting was 25 higher in B than in C. This was believed to be due principally to the lower temperatures in storage C.

The foregoing data indicate the following trends in the Ebenezer onion:

1. The sugars appear to be mainly reducing sugars and sucrose, which may make up approximately 60 percent of the dry matter.
2. Sucrose is the reserve sugar, and prior to storage over 70 percent of the total sugars may be in this form.
3. Common storage practices produce an increase in reducing sugars and a decrease in sucrose.
4. Storage conditions may exist which produce sprouts but which do not significantly increase the rate of respiration in the onions which do not sprout.
5. Slightly lower temperatures may retard sprouting without significantly altering the rate of respiration.

The Progressive Decomposition of Haddock Muscle. (W. S. Ritchie and Philip N. Simon.) Little is known concerning the systematic physico-chemical changes taking place during the decomposition of the muscle proteins of fish. This study is an attempt to elucidate some of the changes in the colloidal nature of the material by means of peptization with neutral salt solutions as decomposition progresses, and by the isolation and identification of the decomposition products of haddock muscle stored under conditions of poor refrigeration.

Much of the effort so far has been confined to an attempt to determine the optimum conditions under which haddock muscle proteins may be peptized by neutral salt solutions. Observations will be made on changes in the peptization values during the storage of haddock muscle. Preliminary data point to an increase in the percentage of total nitrogen peptized by sodium chloride solutions, as the storage time is prolonged. The greatest peptization values for sodium chloride solutions appear to lie between concentrations of 1.5 and 2.5 normal, other cencentrations following a typical peptization curve.

Isolation and possible identification of the decomposition products of haddock muscle are being attempted from fillets stored at 10-12° C. for 20 days. Samples taken at frequent intervals during storage demonstrated a regular increase in volatile nitrogen. However, samples distilled under reduced pressure with magnesium oxide yielded more volatile nitrogen than did identical steam-distilled samples, the difference in value increasing with storage time.

THE CRANBERRY STATION

East Wareham, Massachusetts

H. J. Franklin in Charge

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.)

Fire Beetle (*Cryptocephalus incertus*). Over a hundred acres, mostly in Bourne, Wareham, and Rochester, were found more or less seriously infested with this pest in the summer of 1939, the infestations in all cases having continued from 1938. Eighty acres were treated very successfully by spraying somewhat after mid-August with 3 pounds of lead arsenate in 100 gallons of water, 250 gallons to the acre.

A few of the beetles were found on August 7, and 25 of them to 50 sweeps of an insect net were taken on August 11 on a bog from which the winter water was let off early in April. A few were found on another early-drawn bog by August 13.

Cranberry Weevil (*Anthonomus musculus*). Application early in June of 100 pounds per acre of bran poisoned with 5 pounds of sodium fluosilicate and moistened with water failed completely as a control for the beetles. A like application with oil in place of the water gave the same result.

Alorco cryolite, 9 pounds in 100 gallons of water, applied 400 gallons to the acre on July 31, killed 80 percent of the newly emerged adults.

Cranberry Spittle Insect (*Clastoptera saint-cyri*). A considerable infestation of the adults of this species was killed completely by dusting with 100 pounds to the acre of 4 percent rotenone derris (without an activator or wetter). Nine pounds of cryolite in 100 gallons of water, applied 400 gallons an acre, had no noticeable effect on them.

Colaspis Root-worm (*Colaspis brunnea* var. *costipennis*). Adults of this pest of grape, strawberry, apple, timothy, and corn were found abundant on a bog near West Wareham in late June and early July. They fed freely on the cranberry foliage, blossom buds, and flowers. Their grubs had evidently eaten the fibrous roots of the vines somewhat and eaten the bark off along the vines just below the surface of the sand. A new brood of the grubs, half grown, was found in the cranberry turf of the affected area in the fall, so the species evidently hibernates as a grub. Over half an acre of the bog was in poor condition from the work of the insect, some of it with few or no vines, showing that the infestation had been there several years.

The writer observed a similar, but less important, infestation of this insect on a bog in South Carver about ten years ago. The grubs are much like those of the Cranberry Rootworm (*Rhabdopterus*) and the beetles are somewhat smaller than those of that pest and have yellow stripes on the wing covers.

Hill Fireworm (*Tlascala finitella* (Walker)).[1] This common name is given here to a worm which, this season, seriously infested an area replanted in the spring of 1939 at Greene, Rhode Island. The worms destroyed all the foliage on cranberry vines in the hills on about an acre and a half and did much harm on two and a half acres more. They did not attack any area well vined over. They did most of their work late in July and left a thick mass of their frass and dropped leaves on the sand around the bases of the defoliated plants of each hill. From one to three worms were found on the sand and close to the bases of the plants of each hill. They spun silk very copiously around the lower parts of the plants on which they worked and made extensive loose tubes of it in which they hid. They incorporated sand freely in these tubes on and near the ground and also their frass which they dropped in remarkable abundance.

These worms were very active and jumpy when disturbed. Most of them were full grown by August 2 and some had pupated. When mature, they enveloped themselves in a cocoon of silk and sand on the surface of the sand and soon pupated in it. Nearly all of them had pupated by August 16. The moths emerged from August 20 to September 5. Some pupae remain at the time this is written (November 27), but they seem to be parasitized.

The descriptions of the mature worm, pupa and moth follow:

Worm: Length, about five eighths of an inch. Head mostly blackish. Cervical shield blackish, with a broken yellow stripe along the front margin. Body dark brown, striped lengthwise on the back and sides with about eight narrow and broken pale yellow stripes. Venter without stripes. Back and sides with noticeable scattered pale hairs.

Pupa: Slender, about two fifths of an inch long. Head end and wing covers dark olive green. Abdomen mostly chestnut brown. Caudal segment dark brown, with a small hook on each side of the apex recurved ventrad.

Moth: Length to wing tips, about three eighths of an inch. Wing expanse, about three quarters of an inch. Forewings dark gray above, with cross tufts of black or black-tipped erect scales near the base, about a third of the length from the base and somewhat beyond the middle of each; uniformly smoky below. Hindwings pale with smoky front and outer margins. Head (except eyes), palpi, and basal parts of antennae dark gray. Thorax dark gray above, light gray below. Legs dark gray. Dorsum of abdomen dark gray with fringes of pale yellow along the hind margins of the middle segments; venter colored similarly but with pale marginal hind fringes on all the segments.

Very little of the biology of this species has been known hitherto. It ranges from Canada to Florida but is more common in the South.

The writer observed a less important attack of this pest several years ago on a bog newly planted that spring in East Middleboro. That infestation, though untreated, failed to appear the next year.

Atlantic Cutworm (*Polia atlantica*). An outbreak of this species was described in the last annual report of the cranberry station.[2] The pupae mentioned there as remaining in late December lived through the winter, moths emerging on May 21 and 23, 1939. The description of the moth follows:

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[1] Identified by Mr. Carl Heinrich of the U. S. National Museum.

[2] Mass. Agr. Expt. Sta. Bul. 355, p. 39, 1939.

Length to wing tips, about eleven sixteenths of an inch. Wing expanse, nearly an inch and a quarter. Head mostly medium brown. Thorax mostly medium brown dorsally but with a whitish collar in front margined behind with black. Thorax below and legs light to dark gray. Abdomen mostly gray or smoky brown, with much pale yellow at the tip on the males. Forewings variegated above with gray and medium brown, with a narrow streak of black running out from the base and touches of black near the middle and toward the outer margin, and with a very irregular pale yellow or whitish line running across the outer end a little back from the border. Hindwings smoky above, gradually lighter toward the base. Underside of wings grayish brown of varying shade, that of the hind pair whitish toward the base of the hind side and with a darker dot near the center.

Gypsy Moth (*Porthetria dispar*). Numerous applications of various derris dusts (with and without activators and wetters), up to 100 pounds an acre of 4 percent rotenone derris (without activator) and of derris dusts with moderate admixtures of pyrethrum powder failed to give satisfactory kills of the largely grown caterpillars of this pest. Dusting to control them in any way with rotenone materials seems entirely impracticable.

Cranberry Root Grub (*Amphicoma vulpina*). Studies of the life history of this pest in recent years have shown that the grubs remain in the soil four or five years depending on their luck in obtaining food. Due to this variation, grubs hatched in several different years often come to be associated in the soil.

The cyanide treatment, used extensively for this pest with more or less success for several years, is somewhat dangerous when applied carelessly, sometimes fails to be effective enough, and takes too much time. A more satisfactory insecticide control is therefore much desired. For this reason, the following treatments were tried on infested plots late in April:

1. Sodium fluoride up to a pound in 50 gallons of water, applied a gallon to a square foot.
2. Semi-colloidal arsenate of lead up to 12 ounces in 50 gallons of water, applied half a gallon to a square foot.
3. Sodium arsenite up to half a pound in 50 gallons of water, applied a gallon to a square foot.
4. Sodium fluoride up to 1000 pounds an acre, applied as a dust.

The plots were examined late in August and it was found that none of the sodium fluoride or arsenate of lead treatments had reduced the grubs materially. The vines on the areas dusted with sodium fluoride were badly injured and most of the water applications of this chemical had the same effect. Most of the vines and 75 percent of the grubs on the plot treated with 6 ounces of sodium arsenite in 50 gallons of water and all the vines and all the grubs on the plot treated with half a pound in 50 gallons were killed.

On October 13, a pint of dichlorethyl ether in 50 gallons of water was applied to different infested plots at rates of 1, 2, and 4 quarts to a square foot. These plots were examined November 20; the odor of the chemical was still strong in the soil of all of them and the conditions of the grubs were as follows:

1. Treated with 1 quart to a square foot—20 alive, 12 dead
2. Treated with 2 quarts to a square foot—31 alive, 33 dead
3. Treated with 4 quarts to a square foot—0 alive, 31 dead

The cranberry vines on the last plot were badly injured.

Cranberry Fruit Worm (*Mineola vaccinii*). The season's experience in controlling this pest with rotenone-bearing sprays and dusts, in both experimental work and commercial practice, was in complete accord with that of previous years. A pound and a half of soap in the spray mixture, however, was found enough.

The dust containing 2 percent of rotenone and an activator and wetter was again beautifully effective when used twice, at the proper times, at the rate of 100 pounds an acre. Derris dusts of one and a half and one percent rotenone content with activators and wetters, used twice at 100 pounds an acre and well timed, failed to give satisfactory control. Some of the cranberry growers used 50 pounds to the acre of 4 percent rotenone derris dust without an activator and were well pleased with their results.

Alorco cryolite, 6 pounds in 100 gallons, 400 gallons an acre, and cryolite dust, 30 pounds an acre, were used in Carver on July 15 and again on July 25, times when rotenone materials were effective. The fruit worm was controlled almost completely without material injury to vines or fruit, though the first spray seemed to dwarf the berries a little. Samples of the fruit, scooped from the treated areas on September 9, were analyzed for fluorine residues by the Fertilizer and Feed Control Division of the station at Amherst. The fluorine residue on berries from the sprayed plot was .0023 grains per pound of fruit; from the dusted plot, .000945 grains per pound of fruit. When these residues are compared with the legal tolerance of .020 grains per pound of fruit set for fluorine, the danger in this connection from using cryolite seems negligible. It should be noted, however, that over 4 inches of rain fell in a single storm the last of August in the region where these treatments were applied. The rainfall otherwise between the use of the cryolite and the picking of the samples was light.

On August 10, a bog in East Sandwich with a third of the berries already infested with fruit worms was sprayed with 6 pounds of cryolite in 100 gallons of water, 400 gallons an acre. The control obtained was excellent, the worms doing very little further harm while they took all the fruit on untreated ajoining areas. The berries were picked September 19 and had a fluorine residue of .00084 grains per pound of fruit.

It may be best to use rotenone materials, in spite of their higher cost, in the first treatment for the fruit worm, because they are somewhat safer and because they will at the same time check the blunt-nosed leafhopper, the spittle insect, and the second brood of the black-headed fireworm. The second treatment probably should be with cryolite dust because of the low cost for material and application — only about $4.50 an acre. The dust leaves less residue than the spray (see analyses above). It is less likely to harm the crop at the time of the second treatment than it is when the first is applied.

Black-headed Fireworm (*Rhopobota*). The second brood of this insect was treated very successfully on a number of areas with about 50 pounds to the acre of 4 percent rotenone derris dust without an activator.

Blunt-nosed Leafhopper (*Ophiola*). On July 6, an area with a leafhopper infestation of 310 to 50 sweeps of the net was dusted with a diluted derris dust containing one and a half percent of rotenone, camphor oil as an activator, and a wetter, 95 pounds to an acre. It was examined July 16 and then had only one hopper to 50 sweeps of the net.

On July 11, an area with 450 hoppers to 50 sweeps was dusted with a diluted derris dust containing one percent of rotenone, peanut oil as activator, and a wetter, 100 pounds to an acre. There was a considerable rain on this area for 15 minutes in the morning and another of the same duration in the afternoon on July 12. Only 26 hoppers to 50 sweeps remained on July 16, the kill having been 94 percent. Another area treated and examined on the same dates and in the same way, except that 91 pounds of dust an acre and camphor oil as an activator were used, showed a kill of 94 percent. In relation to their effectiveness, these treatments seem to be as cheap as any that have been tried on this pest so far, the cost of materials and application being about $10.00 an acre. Judging by these results, it seems probable that 50 pounds of 4 percent rotenone derris (without an activator or wetter) an acre will be very effective, but this remains to be tried.

Extensive commercial control of this leafhopper began in 1933. Observations of the results obtained since then indicate that, once control is established, treatment is not necessary on most Massachusetts bogs oftener than once in three years if it is thorough when it is applied. Evidently the hoppers do not travel far en masse and come onto bogs of average size from surrounding uplands very slowly. An infestation of over three hoppers to 50 sweeps of an insect net calls for treatment at any time. Because of the rising cost of pyrethrum products and the falling cost of rotenone dusts and the blanket effectiveness of the latter on the fruit worm, the black-headed fireworm, and this leafhopper, the time for treatment may shift in many cases from the last week in June to around July 10.

Pyrethrum Dusts. There have been many puzzling failures of these materials to control cranberry pests. Checkings of stated pyrethrin content lead to the conclusion that these have probably nearly always been due to inferior quality of the material used. The purchase of pyrethrum from large local distributors who can have the pyrethrin content of the dust they are handling determined is a protection here.

Prevalence of Cranberry Pests. The relative general abundance of cranberry pests in Massachusetts in the 1939 season was as follows:

1. Gypsy moth more abundant in Plymouth county than in 1938, being quite troublesome in some localities; extremely destructive on the middle and outer Cape, even more so than in 1938.
2. Blunt-nosed leafhopper (*Ophiola*) even scarcer than last year, due to general treatment.
3. Cranberry fruit worm (*Mineola*) generally less prevalent than normal, less so than in 1938.
4. Black-headed fireworm more prevalent than last year but widely controlled by disease.
5. Firebeetle somewhat reduced from 1938 (see above).
6. Green and brown spanworms slightly increased from 1938.
7. Cutworms definitely less than last year and less than usual.
8. Cranberry girdler (*Crambus*) and Spittle insect (*Clastoptera*) about the same as in 1938 and rather less than normal.
9. Cranberry root grub (*Amphicoma*). There seems to be a slow general increase of this pest from year to year in spite of effective treatments.
10. Weevil (*Anthonomus*) about as last year, more prevalent than normal.
11. Tipworm (*Dasyneura*) widely prevalent.

Control of Cranberry Bog Weeds. (Chester E. Cross.) During the months of June to September, inclusive, 730 weed control plots were treated. Of these, 410 were treated variously with water-white kerosene and the rest with the following, alone and in some combination: Sodium chloride, calcium chloride, sodium chlorate, sodium arsenate, copper sulfate, ferrous sulfate, ferric sulfate, cyanamid, and ocean water. Results of 1938 work were also examined. The following findings from all this are of particular interest.

1. Water-white kerosene, 800 gallons an acre, applied in early November with a watering can, eradicated a thick lot of rice cut-grass (*Leersia*) nicely.
2. A large number of plots was used to compare the weed control values of the kerosenes of the following producers: Atlantic Refining Co., Cities Service Refining Co., Colonial Beacon Oil Co., Gulf Oil Corp., Shell Oil Co., Socony-Vacuum Oil Co., and Texas Co. These concerns very kindly loaned the Cranberry Station drums to hold the kerosenes. No definite relation was found

between the performance of these oils and the analyses provided by the producers. All the plots treated in June, July, and August showed some cranberry vine injury, but the Cities Service and Colonial products did definitely more harm than the others. The Gulf, Shell, and Atlantic kerosenes burned the vines least. All the kerosenes seemed to have about the same power to kill weeds.

3. An attempt was made to find more precisely the best ways to apply kerosene. The watering can distributes the oil much faster than hand sprayers and therefore tends to make heavier and more effective applications, but it is harder to secure an even and complete coverage with it. The same kerosene applied to equal areas in equal amounts with a watering can and a sprayer burned the cranberry vines to the same extent.

4. Bushes of the hoary oı speckled alder (*Alnus incana*) up to 2½ feet tall were killed readily at any time during the summer with half a pint of kerosene poured about the base, and a pint killed bushes up to 6 feet tall, these shrubs, like the coarse bramble, being very root tender to this oil. The foliage of the treated bushes remained green from 2 to 4 weeks and then suddenly turned brown and dry; the coarse bramble is apt to stay green for a month after the treatment and may even bloom before it dies. The small bushes may be killed by spraying the tops with kerosene, but large ones were not much affected by such spraying even when it was heavy.

5. Ferric sulfate, 2400 pounds to an acre, eradicated sensitive (*Onoclea*) and feather (*Dryopteris*) ferns completely and 95 percent of horsetail (*Equisetum*). It did not injure the cranberry vines much early and late in the season, but was very harmful to them in July and August.

6. Ferrous sulfate mixed 9 to 1 with sodium chloride and placed in single large handfuls at the bases of royal and cinnamon ferns (*Osmunda*) completely eradicated them with less injury to cranberry vines than was caused by controls previously advocated.

7. Sodium arsenate, 1½ pounds in 100 gallons of water applied lightly in August, was very effective in eradicating partidge pea and false pimpernel.

8. July applications of ocean water showed that 3200 gallons an acre were necessary to completely destroy haircap moss. The moss showed no recovery 2½ months after this treatment. The cranberry vines were not harmed by it.

No bog flooded by the tide of the September 1938 hurricane had any living haircap moss in 1939.

9. The conclusion of last year that a fine spray of 100 pounds of sodium chloride in 100 gallons of water is safe to use in treating the wild bean (*Apios*) if less than 200 gallons to the acre is applied was confirmed. Injury to the cranberry vines from this spray has always been due to the use of excessive amounts rather than to the concentration. The nozzles must be held high enough to prevent driving too much of the material into thick foliage.

10. About 100 tests of pulverized and granular cyanamid were made on 42 kinds of bog weeds. Wherever the weeds were killed, the cranberry vines suffered also.

Engineering Projects. (C. I. Gunness and H. J. Franklin.) The study of home cold-storage of cranberries carried on in 1936, 1937, and 1938 and the trial of wind machines for protecting bogs from frost, begun in 1938, were continued, the Cranberry Station cooperating with the Department of Engineering. See the report of the Department of Engineering.

COOPERATIVE CRANBERRY INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Massachusetts Agricultural Experiment Station

H. F. Bergman, Senior Pathologist, U. S. D. A. In Charge

Development of Strains of Cranberry Resistant to False Blossom. (H. F. Bergman and W. E. Truran.) Berries from crosses made in 1938 were sent to the U. S. Horticultural Station, Beltsville, Md., where the seeds were germinated and the seedlings grown. From a total of 353 fruits 8,233 seeds were obtained which produced 6,337 seedlings. In July 1939 there were 6,291 plants. These will be taken to New Jersey and set out on a bog in 1940. Because of the lack of bog area for use in testing hybrid seedlings no crosses were made in 1939.

Studies on Flower and Fruit Production. (H. F. Bergman and W. E. Truran.) Studies to determine the effect of oxygen content of winter flooding water on flower and fruit production have previously been made. Previous observations have shown that the average flower production in the Early Black, Howes, and McFarlin varieties, under favorable conditions, is about four flowers per upright. Flower production in Early Black on section 14 of the State Bog, in 1939, was about the normal average. In Early Black on the Star Bog and in McFarlin on the State Bog flower production was less than the average by one flower per upright. Elsewhere on the State Bog the difference was greater, amounting to about one and a half flowers per upright in Howes on section 13 and to about two flowers per upright in Early Black on section 4 and in Howes on section 7. A correlation with weather conditions could not be determined from available data.

The average percentage of fruit set in any of the three varieties, under favorable conditions, varies from 30 to 35. The set in Early Black on section 14 in 1939 was less than half this average. The highest percentage of fruit set, on the State Bog, was 18.6 in McFarlin, the lowest 7.6 in Howes, both on section 13. The low percentage of fruit set appears not to be correlated with the oxygen content of the winter flooding water. It seems possible that the low rainfall during July 1939 may have had an effect on the setting of fruit and may partly explain the variation in set in different locations on the State Bog. The Howes vines on section 13 were on higher ground than elsewhere and might be expected to have had the least water supply; the McFarlin vines were in one of the lowest spots on the bog and probably had the best water supply. The water supply of vines in other locations on the State Bog was intermediate. This is in agreement with the observed set on vines in the different locations. Furthermore, the percentage of fruit set by flowers on uprights from large terminal buds was less than on uprights from medium or small terminal buds in all locations on the State Bog except in McFarlin on section 13. This is in conformity with the suggestion that the reduction in the percentage of fruit set may have been due to a lack of water. The proportion of uprights with three or more flowers per upright is greater in uprights from large terminal buds than in uprights from medium or small terminal buds and a lack of water would affect the set of fruit on uprights with three or more flowers more seriously than on uprights with only one or two flowers.

Spraying Experiments for the Control of Rosebloom. (H. F. Bergman and W. E. Truran.) Bordeaux 4-1-50 and 5-2-50, a red copper oxide–bentonite mixture 2-2-50, and yellow copper oxide 1½-50 were each applied once (June 12) on duplicate plots on a bog badly infected with rosebloom. Bordeaux 5-2-50 gave the best control. Within three days after the spray was applied diseased shoots had turned black and shriveled, and no unaffected or only partly killed diseased shoots could be found. Bordeaux 4-1-50 was only a little less effective than the 5-2-50 and was superior to either the red or yellow copper oxides. Both the red and yellow copper oxides were much slower in action than bordeaux mixture and did not kill out the rosebloom as completely as did bordeaux. A week after rosebloom had been killed out by bordeaux mixture, living unaffected or only partly killed diseased shoots could be found on plots sprayed with either red or yellow copper oxide.

Spraying Experiments for Cranberry Rot Control. (H. F. Bergman and W. E. Truran.) Spray tests were run on four bogs, on plots of 1/20 acre area. All sprayed plots received two applications, at the rate of 250 gallons per acre; the first when

Treatment	Bog	Number of Plots	Average Percentage Rot		
			Oct. 1	Nov. 1.	Dec. 1
Bordeaux 5-2-50 (high Ca)	State S 8	2	1.0	2.8	10.1
Bordeaux 5-2-50 (high Ca)	State S 14	4	1.3	4.9	12.7
Bordeaux 5-2-50 (high Ca)	No. 3	4	8.9	16.5	26.8
Bordeaux 5-2-50 (high Ca)	No. 7	4		4.7	10.1
Bordeaux 5-5-50 (high Ca)	No. 9	3	3.6	9.3	13.3
Bordeaux 5-2-50 (high Mg)	No. 9	3	5.4	10.0	14.2
Bordeaux 5-2-50 (high Mg)	State S 8	2	0.8	4.9	11.5
Check*	State S 8	3	1.4	7.6	18.3
Bordeaux 5-3-50 (high Ca) + ½ lb. zinc arsenite	State S 8	2	1.0	3.8	13.8
Check*	State S 8	2	2.7	12.0	24.3
Bordeaux 5-3-50 (high Ca) + ½ lb. zinc arsenite	No. 3	2	9.0	16.3	28.7
Bordeaux 5-3-50 (high Mg) + ½ lb. zinc arsenite	No. 3	2	11.6	21.1	31.2
Bordeaux 5-3-50 (high Ca) + ¾ lb. zinc arsenite	State S 8	2	0.9	2.8	11.7
Check*	State S 8	2	1.6	8.0	16.9
Bordeaux 5-3-50 (high Ca) + ¾ lb. zinc arsenite	No. 7	2		3.8	9.2
Check*	No. 7	2		27.8	35.8
Bordeaux 5-3-50 (high Mg) + ¾ lb. zinc arsenite	No. 7	2		5.2	12.1
Check*	No. 7	2		21.1	37.2
Bordeaux 5-3-50 (high Ca) + 1 lb. zinc arsenite	State S 8	2	0.9	3.5	13.1
Check*	State S 8	2	1.7	6.6	14.8
Cuprocide — bentonite	No. 7	3		4.3	9.5
Cuprocide 54Y (1½-50)	State S 14	2	1.1	3.7	10.9
Check*	State S 14	2	1.4	8.0	16.2
Cuprocide 54Y (2-50)	State S 14	2	1.2	4.0	10.3
Check*	State S 14	2	3.1	10.0	19.8
Cuprocide 54Y (1½-50)	No. 3	2	9.1	18.8	30.2
Cuprocide 54Y (2-50)	No. 3	2	9.2	15.7	27.4
Cuprocide 54Y (1½-50)	No. 9	3	6.2	12.3	14.2
Phenothiazine 2-50**	State S 14	2	1.4	6.4	15.4
Check*	State S 14	2	1.5	7.3	15.2
Phenothiazine 2-50	State S 14	2	2.2	7.2	16.7
Check*	State S 14	2	3.5	11.7	21.4
Check	State S 8	4	2.5	10.1	19.1
Check	State S 14	5	2.2	8.8	17.1
Check	No. 3	5	17.6	34.7	44.5
Check	No. 7	5		25.8	38.5
Check	No. 9	5	39.7	52.8	56.5

*Figures here given apply only to plots indicated on line above; in all other cases values for check plots as given at bottom of table apply.

**No wetting agent.

the flower buds were just ready to open, and the second when the petals had fallen from most of the flowers. The results are shown in the table.

The degree of rot control obtained by the use of the several spray mixtures was greatest during the period from October 1 to November 1 and thereafter declined, sometimes markedly so, because of an acceleration in the rate of spoilage of the berries from so many of the sprayed plots after November 1. The acceleration in the rate of spoilage after November 1 seems not to be correlated with spray treatment, as the same thing was observed in berries from one or more plots sprayed with any one of the several spray mixtures used and also in berries from plots not sprayed. In some instances it appeared to be correlated with local conditions on the bog but this could not be established in all cases.

Blueberry Disease Investigations. (H. F. Bergman and W. E. Truran.) Isolations of a fungus causing "wilt" on two bushes of unselected hybrids at the State Bog were made at intervals during the growing season. Both bushes are badly diseased and are known to have been diseased for the last three years at least. *Phomopsis* was isolated consistently from both diseased leaves and stems and appears to be the causal organism.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

Nutritive Value of Chocolate Milk. (W. S. Mueller and N. L. Keyock.) The nutritive value of chocolate-flavored milk is being studied by animal experimentation. A chocolate syrup which is practically free from theobromine, cocoa fiber, and cocoa fat was compared with a product which contains these substances in ordinary amounts. In both cases the chocolate milk was made from one part of syrup to ten parts of fluid milk (3.5 to 4.0 percent butter fat). Plain milk served as an additional control. Three groups of eight rats each were fed for five weeks.

In general, the rats on the plain milk and those on the special chocolate milk were the extremes, with the rats on ordinary chocolate milk about midway between. The rats on the plain milk diet gained least in weight, were the most active, excreted the most urine, and the pH of the urine was lowest. Here, however, the consistency ends, for the rats on the ordinary chocolate milk showed a slightly higher acidity of urine than the plain milk group, while the figure for the rats on the special chocolate milk was very much lower. The figures for specific gravity of urine were highest for the plain milk group and lowest for the rats on the ordinary chocolate milk.

More data are necessary before the results can be interpreted.

The Effect of Cocoa upon the Digestibility of Milk Proteins. (W. S. Mueller and L. D. Lipman.) The purpose of this study was to determine whether or not the addition of cocoa had any adverse effect on the digestibility of milk proteins. Both "in vitro" and animal feeding have been used in this study of three different cocoa powders: a Dutch-process, an American-process, and a blend of Dutch and American cocoa powders.

Experiments in vitro showed that, as the concentration of the cocoa blend was increased from 1 to 2.5 to 4 percent, the digestibility of the milk proteins was reduced 3.1, 8.2, and 12.4 percent, respectively, after four hours' digestion. The addition of 4 percent Dutch cocoa or American cocoa reduced the digestibility of the milk proteins 11.8 and 13.7 percent, respectively. As the percentage of butter fat was increased from 0 to 2 to 4 percent, the digestibility of the milk proteins of a chocolate milk containing 4 percent of American cocoa was reduced

13.6, 12.9, and 12.5 percent respectively. When reconstituted milks were used, the reduction was 16.7, 13.7, and 11.4 percent for skim milk, part skim milk, and whole milk. As the butter fat content of the chocolate milk was increased, the digestibility of the milk proteins tended to increase.

In feeding experiments, white rats were able to digest 85, 71, 69, and 71 percent, respectively, of the protein when the feeds contained milk powder, milk powder plus 4 percent American cocoa, milk powder plus 4 percent Dutch cocoa, and milk powder plus 4 percent American cocoa and 2 percent cocoa fat. The digestibility of the milk proteins was reduced only 7 percent by the Dutch and 6 percent by the American cocoa and appeared to be unaffected by the cocoa fat.

Nutritive Value of Milk Flavored with a Water Extract of Cocoa. (W.S. Mueller.) The purpose of this study is to determine whether a water extract of cocoa has the same effect as cocoa powder on the nutritive value of the milk. The following diets were fed to three groups of eight rats each: Plain whole milk, whole milk plus 3 percent cocoa, and whole milk plus 6 percent of concentrated water extract of cocoa, with sugar, sodium alginate, and minerals added to all three. The concentrated water extract was made from 50 grams of cocoa per 100 c. c. of water, and enough was added to the milk so that the rats received the extract obtained from the same amount of cocoa that was fed to the animals on the cocoa powder diet. The principle of the paired feeding method was used through a period of 12 weeks. Animals receiving the plain milk and the milk plus cocoa extract made about equal gains in weight, which were higher than the gains made by the animals receiving milk plus cocoa powder. After the animals had been on test for eight weeks, the extract group was more active than the control group and the cocoa powder group was the least active of the three. A decrease in the volume of urine was noted for the cocoa extract group, and their urine was higher in acidity than that produced by the plain milk diet. On the other hand, the urine from the animals receiving cocoa powder was lower in acidity than that of the control group.

The cocoa powder used in this experiment contained 2.5 percent cacao red, while the water extract of the same cocoa contained only a trace. The results of this study as well as previous nutritional studies indicate a correlation between the digestibility of the chocolate milk and the amount of cacao red in the chocolate flavoring material. This phase of the study is being investigated further.

Improving the Flavor and Keeping Properties of Milk and Some of Its Products. (W. S. Mueller and M. J. Mack.) This project deals chiefly with antioxidants for milk and some of its products. The antioxidative properties of various cereal flours have been described in a paper published in *Food Research* 4 (No. 4):401-405, 1939 (Contribution 337).

The antioxidative properties of various sugars are now being investigated. Sugar itself has antioxidative properties and is also a suitable carrier for the antioxidative substance obtained in extracts from oat and corn flour and other materials. Results to date indicate that the antioxidative property of sugar is affected to a greater extent by the refining process than by the kind of sugar.

Cocoa was found to contain a powerful antioxidative substance which could be removed in the water or alcohol extract. The concentrated extract proved to be an effective antioxidant for milk when used alone or in conjunction with a carrier such as skim milk powder. Decolorizing the water extract of cocoa, however, removed most of its antioxidative properties.

The addition of .05 percent of d-gluco ascorbic acid and butyl ester of tyrosine prevented an oxidized flavor in susceptible milk.

The Effect of Aging Treatments on Gelatin and Other Ice Cream Stabilizers. (W. S. Mueller.) An explanation for the effect produced on gelatin solution by the higher initial aging temperature was sought by studying properties of gelatin which are likely to be influenced by the gel structure or which would serve as an index to the colloidal behavior of the gelatin. In addition to studies of viscosity, gel strength, optical rotation, and light scattering, which have been described previously, studies were made during the past year of electrical conductance, gold number, and effect of agitation.

The higher initial aging temperature of 68° F. had no significant effect on the velocity of the hydrogen ion through the gelatin gel when compared with an aging temperature of 38° F. for the entire period. However, the higher initial aging temperature decreased the velocity of chromate ions through the gelatin gel when compared with the lower temperature. The decreased rate of migration of chromate ion through the higher initially aged solution suggests a more closely knit structure. The rate of the hydrogen ion was not affected, probably because of its smaller size.

Gold number determinations must be made with very dilute gelatin solutions, which may explain why the higher initial aging temperature did not increase the protective action of the gelatin.

Agitation of the gelatin solution while it was held at the higher initial aging temperature was found to increase the gel structure. If an increase in viscosity retards gel structure building, then it may be expected that agitation within limits will facilitate gel structure formation in that more frequent collisions of gelatin micelle may occur.

Several other ice cream stabilizers were compared with gelatin with respect to their response to high aging temperatures. Water solutions of karaya gum, oat flour, sodium alginate, and agar-agar were initially aged at 68° F. for five hours. Agar-agar was the only substance affected by the higher initial aging temperature. Both apparent and basic viscosity were increased when the high initially aged solution was compared with a solution aged only at 38° F. However, the increase was more pronounced for the apparent viscosity.

The Use of Egg Solids in Ice Cream. (M. J. Mack.) Egg solids have been used in ice cream since the very beginning of the business. The effect of egg yolk on the properties of ice cream was studied here some years ago when only batch freezers were used in the industry. Further work appeared necessary to see whether egg yolk solids were desirable in ice cream made on a continuous freezer. A study of the egg products known as egg powder "blends" also seemed desirable.

The conclusions from the work done during the past year were summarized in a recent article entitled "Egg Solids," by M. A. Widland and M. J. Mack, published in the October 1939 issue of the Ice Cream Trade Journal. Egg yolk solids improved the flavor, body, and texture of ice cream. Such defects as coarse texture and weak or crumbly body are less likely to occur when the egg solids are used. The product also causes the ice cream to appear creamy and smooth when melting and helps to eliminate defects in melting appearance.

The egg yolk blends, which are products containing dextrose, skim milk powder, or egg albumin mixed with dehydrated egg yolk, are of value only to the extent that they contain egg yolk. The use of these products instead of ordinary dehydrated egg yolk should be avoided. Methods of analysis which are suitable for determining the percentage of yolk solids in a powdered egg product are discussed in the paper mentioned above.

Sodium Alginate as a Stabilizer for Ice Cream. (M. J. Mack.) In previous annual reports, it has been shown that this stabilizer is satisfactory for use in ice cream. Since each stabilizer has somewhat different characteristics, the advisability of combining some of the common stabilizers for use in dairy products should be of interest. Preliminary results indicate that certain combinations might be worked out which may prove superior to the use of one stabilizer alone. The study of different combinations of vegetable stabilizers is being continued.

Utilization of Whey By-Products. (J. H. Frandsen and Myer Glickstein.) Various difficulties have been encountered in the effort to perfect a fermented whey drink. When a double fermentation process is used, whereby the whey is fermented first in an open vat, then in capped bottles, either too much or too little CO_2 is likely to be produced. If the conditions are just right for the production of CO_2, the time factor becomes troublesome. When the capped bottles are held for some time in storage, the whey becomes more acid and the flavor begins to deteriorate. The yeast cells apparently autolyze to some extent and produce further off-flavors. If in-the-bottle pasteurization is resorted to earlier in the process when just sufficient gas is produced, the dead yeast cells again give rise to objectionable flavors. Further work now in progress should develop a method whereby the activity of the yeast cells can be retarded just enough to prevent any off-flavor.

Other products made from whey, such as whey honey and whey candy, have been developed to the extent that they have commercial possibilities.

A Study of the Efficiency and the Practicability of the Paper Milk Bottle. (J. H. Frandsen and M. A. Widland.) All paper bottles examined for microorganisms gave plate counts well within the standard of one colony per c. c. capacity, as suggested by the American Public Health Association. The microorganisms that were isolated were harmless saprophytes probably introduced into the containers by the water used in making the paper.

It was found that the volume taken up by the average 12-quart case for glass bottles is about 2700 cubic inches, whereas the volume of paper cases ranges from 740 to 1250 cubic inches, which means a saving of from 53 to 72 percent in storage space. Furthermore, a case of 12 quarts of milk in paper containers is 50 percent lighter than the same amount in glass. Work done also shows a marked saving in refrigeration costs in the case of paper containers.

Paper bottles seem to have no deleterious effect upon the flavor of milk, and even afford some protection against the development of "sunlight" flavor.

DEPARTMENT OF ECONOMICS

Alexander E. Cance in Charge

Land-Use Problems in Massachusetts in Relation to a Balanced Program of Land Utilization. (David Rozman.) A preliminary analysis of land-use factors has been prepared for about one-third of the towns in the Commonwealth, where the relationship between the types of soil, topography, rural roads, and buildings was projected against the existing system of land utilization. This analysis is further considered in the light of local economic and social conditions as reflected in the general movement of the population, available employment opportunities especially in local industries, and trends in land values and taxation, as an indication of the best type of land-use pattern fitting any particular locality.

The results of the investigation completed for Worcester County indicate that out of a total area of about one million acres 15.6 percent is now being used for crops and plowable pasture, 11.5 percent is in stony and woodland pasture, and 63.3 percent is in various types of forest growth; while swamps and wasteland account for 1.3 percent, water bodies occupy 3.7 percent, and settled, commercial, and industrial areas make up 4.6 percent. From the standpoint of the soil analysis and classification, 30.9 percent of the county area is found to be of good adaptability for agricultural development, represented mostly by soils both moist and of good texture; 33.4 percent of only limited adaptability; and 27.4 percent unsuitable for regular agricultural utilization, on account of being either too rough and stony or too wet or dry. The correlation of soil types and topographical conditions with present land uses by individual areas indicates the extent and character of adjustments to be carried out in a community under existing local economic and social opportunities.

The results of this study are being put to practical use in connection with the town rural policy committees which are being organized for the purpose of comprehensive land-use planning in rural areas of the Commonwealth. In forty-five towns where these committees have been organized, information obtained in this study has been used as a basis for working out a detailed program of local planning and land-use development.

DEPARTMENT OF ENGINEERING

C. I. Gunness in Charge

Cranberry Storage Investigation. (C. I. Gunness, H. J. Franklin, and C. R. Fellers.) The work on storage was continued through the 1939 season. Berries were held at 35° and 45° in cold storage and in two screen houses operated by growers. The results obtained were consistent with the results obtained in former years. The storage losses on berries stored from September 10 to November 10 under the three conditions, 35°, 45°, and common storage, were 2.7, 5.5, and 11.3 percent, respectively; and from September 10 to November 30, the losses were 6.7, 9.0, and 17.0 percent in the corresponding storages.

Frost Protection on Cranberry Bogs. (C. I. Gunness.) The work on frost protection on cranberry bogs through the use of a wind machine was continued during the past year. The machine was originally set up as a stationary unit on one side of the bog. During the past season it was mounted on a turntable with the plan of placing it in the center of a dry bog. So far it has been used only on the side of the bog. While the results obtained are quite encouraging, it is felt that insufficient data have been obtained to warrant a statement as to the efficiency of this type of frost protection.

Poultry House Investigation. (C. I. Gunness and W. C. Sanctuary.) A study of the use of electric brooders in insulated and noninsulated colony houses was started this fall. An insulated house will be heated by an electric heater and in two noninsulated houses the floor is heated by means of soil cable in an attempt to keep the litter dry. Another part of the study will be devoted to the effectiveness of insulation in providing a dry, comfortable laying house.

DEPARTMENT OF ENTOMOLOGY

Charles P. Alexander in Charge

Investigation of Materials which Promise Value in Insect Control. (A. I. Bourne and W. D. Whitcomb, Waltham.)

Oil Sprays for Dormant Applications. Climatic conditions during the late winter and early spring of 1939 were characterized by low temperatures and heavy snowfall in March and cold, wet, and generally disagreeable weather during most of April. These combined to retard plant development and produce a season 10 to 14 days later than normal, while frequent high winds and sudden changes of temperature interfered with the application of dormant and delayed dormant sprays.

The infestation of European red mite was very light throughout most of the State and was practically nonexistent in most of the college blocks. On the other hand the overwintering eggs of all species of orchard plant lice were very abundant, and in the college blocks the infestation was the heaviest for many years. Counts from 50 typical branches of both McIntosh and Baldwin trees showed 9,635 eggs on 918 inches of twig on McIntosh, or an average of 10.5 eggs per linear inch; and 6,225 eggs on 683 inches of twig on Baldwin, an average of 9.1 eggs per linear inch.

In a cooperative project with the Dow Chemical Company, tests were made, in the college orchard, of the ovicidal value of various oil sprays; one containing dinitro-ortho-cyclo-hexylphenol (DNOCHP), the oil having a viscosity of 110 sec. Saybolt (the commercial Dowspray Dormant); a similar oil containing dinitro-orthocresol; and a combination of a light oil, of 50 sec. Saybolt, and dinitro-ortho-cyclo-hexylphenol. These sprays were prepared and furnished by the Company. A home-made stock solution of a petroleum oil similar to that used in the commercial DN spray above, combined with the DNOCHP powder and emulsifier, was also prepared and applied. Tests were also made of a commercial spray of this type supplied by the California Spray Chemical Company (Nitro-Kleenup), and of a spray material consisting of a sodium salt of dinitro-orthocresol manufactured by the Standard Agricultural Chemicals, Inc. (Elgetol) and reported to contain no oil. All these sprays were applied while the trees were in dormant condition.

Comparison of sprayed trees and unsprayed checks indicated no mortality to fruit or leaf buds nor any retardation of bud development. An application of a commercial DN spray to a few young trees as the blossom buds were breaking, however, was followed by considerable injury to both fruit and leaf buds. All of the sprays proved very toxic to aphid eggs.

Tests of both the commercial DNOCHP sprays and the home-prepared emulsion were carried on, in collaboration with Mr. Robert E. Huntley of Hanover, in several commercial orchards and private estates in Plymouth County. In most of the orchards rosy apple aphid had been so prevalent during recent years that serious damage had been caused and in many cases the crop was practically worthless. In these tests the sprays again demonstrated the fact that when thorough coverage of the trees was secured very few aphids appeared, whereas unsprayed trees showed from 10 to 50 aphids per bud.

The Huntley estate offered the opportunity to observe for the first time the results of dormant application of commercial DNOCHP spray on a wide range of deciduous ornamentals including birch, catalpa, elm, hawthorn, lilac, maple, oak, poplar, and willow including English laurel-leaf pussy willow, a tender variety quite susceptible to spray injury, as well as a dozen varieties of evergreens including arborvitae, cedar, fir, juniper, pine, spruce, yew, and broad-leaved types such as box, laurel, and rhododendron. Very little, if any, damage was noted on the deciduous ornamentals sprayed, but very general injury, varying in degree from slight burning to serious defoliation, resulted on practically all types of evergreens. In addition to furnishing a very efficient control of those species of aphids which had in the previous season attacked these ornamentals, the sprays showed promising results against oystershell scale, elm scale, and tulip scale. European red mite was so scarce throughout that area that no reliable data could be secured.

Control of Bud Moth with Dormant Sprays. In cooperation with the Dow Chemical Company and H. A. Priest, nine blocks of trees at Fruit Acres, Gleasondale, infested with the bud moth, were sprayed with combinations of dinitro-ortho-cyclo-hexylphenol (DNOCHP) and dinitro-orthocresol in oil, furnished by the Dow Chemical Company; and sodium dinitro-cresylate, and oil emulsion plus nicotine sulfate, furnished by the owner. Approximately 5000 gallons of spray were applied to 600 trees in the experiment. Application was started on April 23 when the buds were in the silver tip stage but was discontinued at noon because of wind and completed on April 24. Three count trees were selected from each plat and an adjoining unsprayed block was used as a check. A bud examination was made on these trees on May 24–25 when most of the trees were in bloom, and the fruit was examined at the regular harvest period for the variety.

In comparison with a bud infestation of 62 percent and fruit infestation of 23.86 percent in the check, all treatments gave excellent control of the bud moth. Considerable injury occurred, especially to leaf buds on one-year-old twigs and also to fruit buds. This injury was most serious where DNOCHP in oil was used on Gravenstein, Yellow Transparent, and McIntosh. Russet trees sprayed with a tank-made mixture of the same materials showed little or no injury. Injury was much more severe on large trees where the drip and drift from the upper branches caused excessive drenching of the lower branches. The DN cresol mixtures appeared least injurious to the trees and gave satisfactory control of the bud moth.

Summer Sprays for Apples. Tests of these materials were conducted in cooperation with the Departments of Pomology and Botany. The widespread damage caused by the hurricane of September 1938 throughout most of the fruit-growing sections of the State naturally led to a study of modifications of the spray program to reduce as far as possible the danger of spray injury to weakened trees and at the same time retain an efficient control of disease and insect pests. Although the hurricane injury in the test block was not so extensive as in more exposed sections of the college orchard, there had been sufficient injury to warrant the use of this block for such studies.

The tests included commercial lime-sulfur at a reduced strength of 1½ gallons per 100 with spray catalizer, similar tests of lime-sulfur at reduced strength with hydrated lime to retard breakdown, two combinations of lime-sulfur and wettable sulfur at half strengths, wettable sulfur at full strength throughout the season, and a wettable sulfur with orthex sticker. All of the above combinations were used in the pre-blossom and calyx sprays followed by wettable sulfur in the four subsequent applications. The standard schedule of lime-sulfur 2 gallons per 100 in the pre-pink, pink, and calyx sprays, and wettable sulfur thereafter, was used as the basis of comparison. Lead arsenate was omitted in the pre-pink application but was included in all others. The dosage was 3 pounds per 100 gallons in the pink and 3d cover sprays; 4 pounds per 100 gallons in the calyx, 1st and 2d cover sprays; and 2 pounds per 100 gallons in the 4th cover spray. Linseed oil was ued in the 1st cover spray.

Examination of the block in early June showed noticeable dwarfing and crinkling of leaves in the trees given the standard schedule. This condition was also present, but to a noticeably less extent, on trees sprayed with lime-sulfur at reduced strength with spray catalizer and lime. The trees which had received the combinations of lime-sulfur and wettable sulfur at half strengths showed no injury up to that time. This was also true where wettable sulfur alone or with orthex sticker was used. Up to that time scab was being successfully controlled in contrast with the unsprayed checks where the foliage was already showing heavy infection. Later in the season when all the trees received wettable sulfur, the new growth showed no spray injury, and on the trees sprayed with lime-sulfur the late growth was composed of large, flat, normal leaves typical of the foliage on trees which received wettable sulfur throughout the season and in sharp contrast to the small, malformed leaves which received the lime-sulfur application. (See photograph on page 49.)

The crop on the Baldwin trees was very light and uneven. Many of the trees had no fruit and those which produced even a light crop bore most of the apples on the west side of the trees, a possible reaction to the hurricane. The McIntosh trees on the other hand fruited heavily and the crop developed to good size and excellent color. The record of the McIntosh crop at harvest indicated that liquid lime-sulfur at reduced strength was measurably safer to foliage without losing its effectiveness against scab. When lime-sulfur was diluted to half the usual strength (1 gallon to 100) and combined with wettable sulfur, it checked scab satisfactorily and caused no appreciable burn. Spray catalizer acted as a protective agent when used with the lime-sulfur–lead arsenate combination and in a large measure reduced the customary lime-sulfur injury to foliage.

Control of Striped Cucumber Beetle. (W. D. Whitcomb, Waltham.) In the experimental planting at Waltham in 1939, the striped cucumber beetle was normally abundant, averaging about 40 beetles per hill on untreated cucumbers and 10 per hill on untreated cantaloupes. More than 75 percent of the beetles were found on cucumbers, thus further emphasizing the preference for this crop.

In general, the influence of the beetle infestation on the yield of fruit was not significant. Continued dry weather prevented the development of bacterial wilt even in the presence of a larger number of beetles, and a heavy infestation of melon aphid was responsible for a general infestation of cucumber mosaic.

In these experiments, treatments were made seven times between June 17 and July 15, while four additional applications were made between July 27 and August 26 to protect the vines until yield records were secured. Under these conditions the most effective materials in reducing the beetle infestation were:

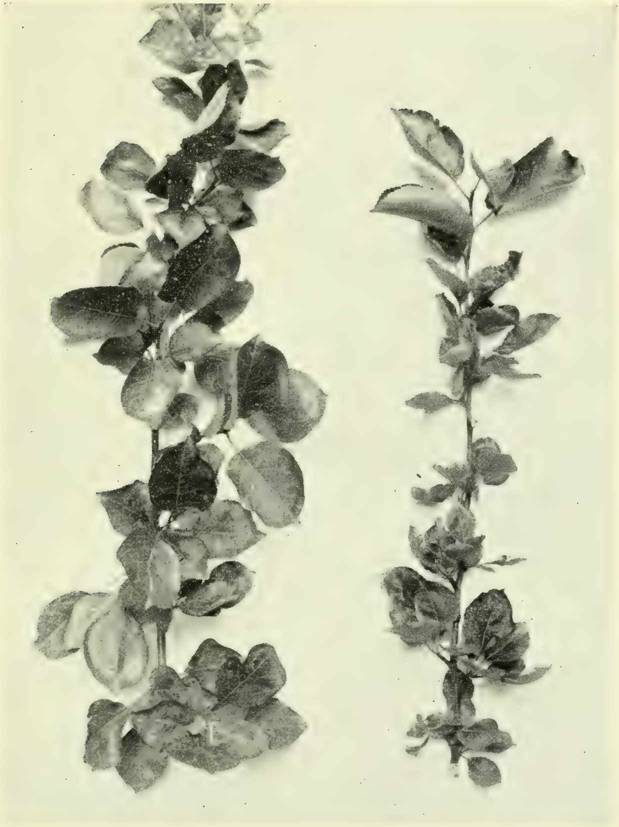
Calcium arsenate–red copper oxide–flour–talc 10-6-10-74
Copper rotenone–talc 4.75 percent copper and .8 percent rotenone
Cube–talc 0.75 percent rotenone
Calcium arsenate–talc 1-14
Calcium arsenate–monohydrated copper sulfate–lime 10-20-70

All of these dusts reduced the beetle population 80 percent or more on cucumbers, and 90 percent or more on the cantaloupes.

Of these materials the calcium arsenate–red copper oxide and the calcium arsenate–monohydrated copper sulfate were the most effective on cucumbers, but the latter caused slight to moderate foliage injury and was much less satisfactory. Applications of fibrous talc alone gave 79 percent protection but showed the lack of a toxic ingredient, while wettable derris spray was ineffective.

In direct comparisons copper oxychloride dust and calcium arsenate were more effective against the beetle with talc as the carrier than with hydrated lime, but a better yield was obtained from vines treated with dust in which lime was the carrier. Calcium arsenate with red copper oxide was more effective on cucumbers, but calcium arsenate with copper zeolite was superior on cantaloupes, and the yield from the cucumber vines dusted with the copper zeolite mixture was the best.

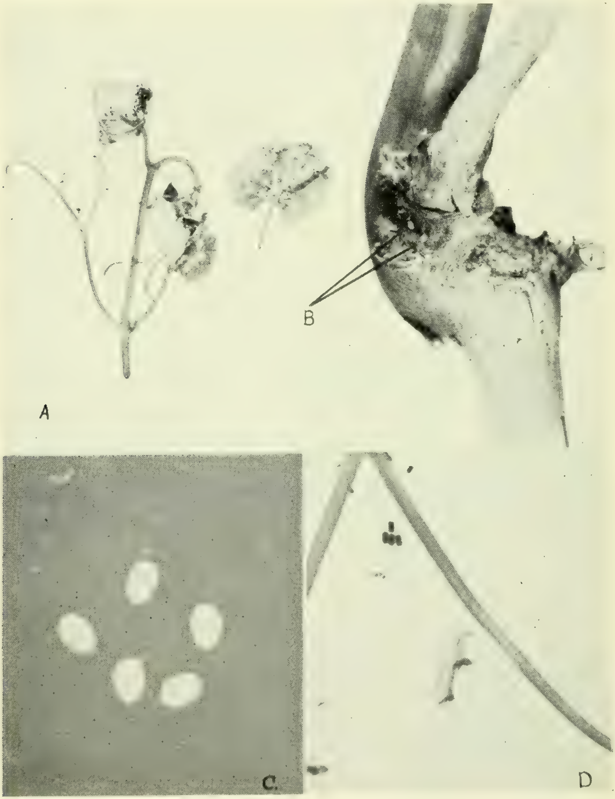
Dusts containing rotenone and those containing calcium arsenate were both effective against the striped cucumber beetle; but better yields were obtained where the calcium arsenate dusts were used and, since they are cheaper, they are preferred.



Injury to Apple Foliage Following Pre-Blossom Applications of Lime-Sulfur

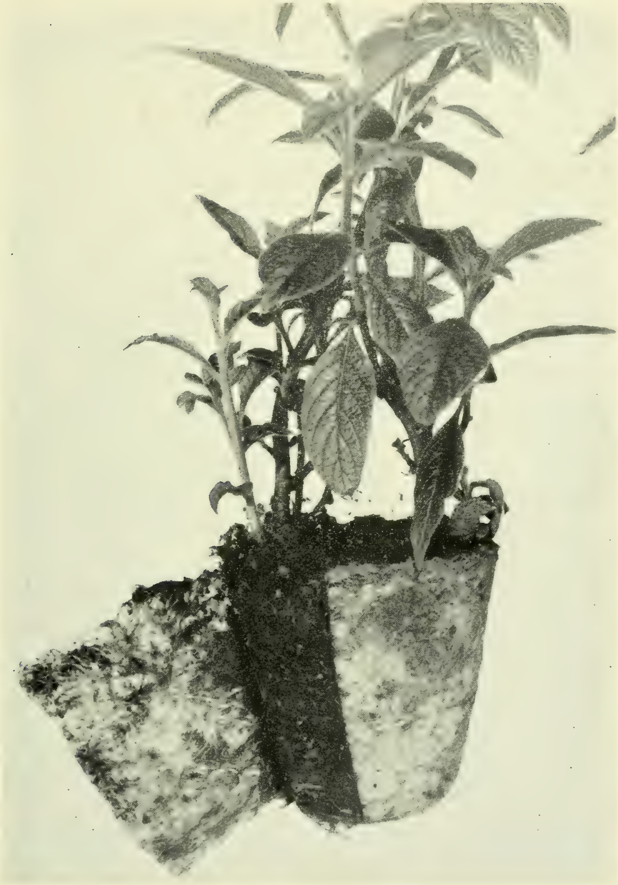
LEFT: Uninjured foliage from Baldwin tree sprayed with wettable sulfur–lead arsenate combination throughout the season. Note abundance of foliage and retention of even the small, earliest leaves.

RIGHT: Baldwin foliage dwarfed and distorted as the result of the use of lime-sulfur–lead arsenate spray in pre-blossom and calyx applications. Note comparatively scanty foliage due to loss of most of the early season leaves. The full-sized leaves at the tip represent growth which has taken place since the calyx application. (See page 48.)

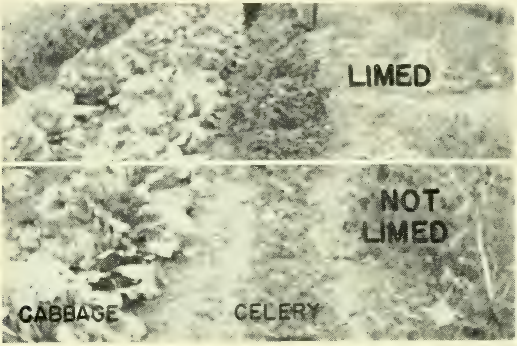


Grape Plume Moth

A. Tip of grape shoot, showing the typical injury; B, Eggs in natural position on grape cane; C, Eggs enlarged 15 ×; D, Pupa enlarged 2½ ×. (See page 64.)

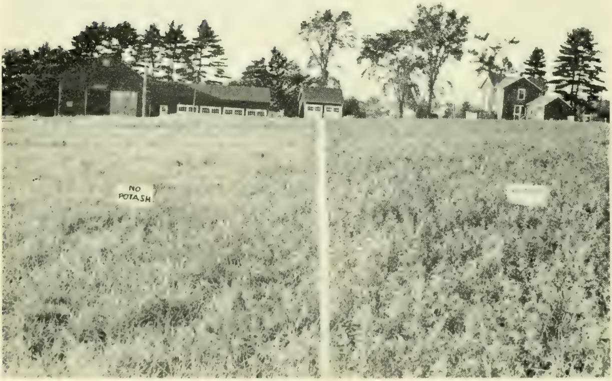


Root systems in porous clay pots tend to concentrate against the pot wall outside the soil mass. When the pot wall gets dry, the adjacent root system may also suffer from drought. Keeping the pot on a moist surface protects the root system. (See page 22.)



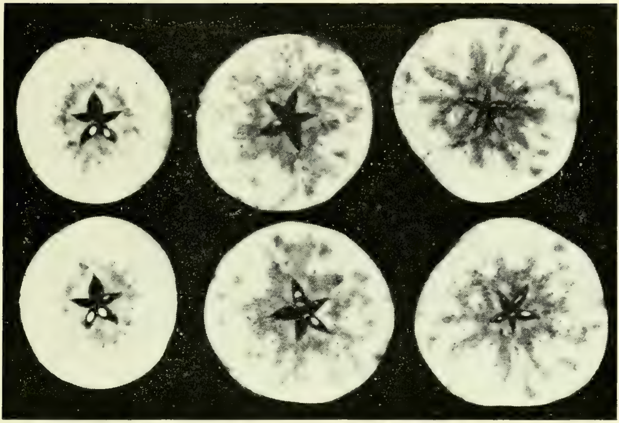
Cabbage and Celery on Limed and Unlimed Plots

Celery showed marked response to liming, while cabbage grew equally well where lime was not applied. (See page 10.)

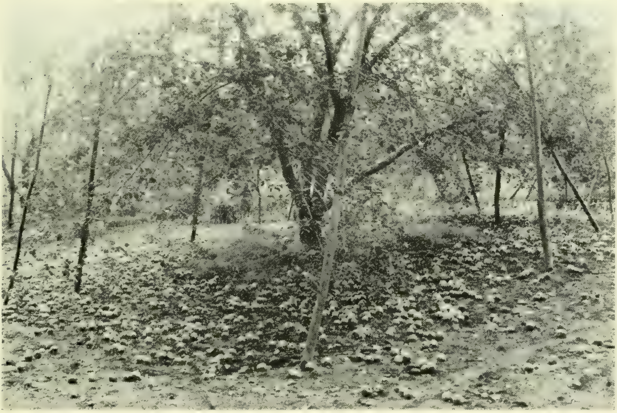


Effect of Potash on Yields of Hay

Disappearance of alfalfa where potash was not applied, while a good stand remained on the area receiving potash, apparently accounts for the wide difference in yield. (See page 15.)



Cortland apples showing internal cork due to deficiency of boron. The condition of these apples does not improve during storage. (See page 87.)



Excessive dropping of McIntosh just before harvest. Development of the use of "hormone" sprays may be a feasible approach to the solution of this problem. (See page 89.)

Typical Plants of the new Trellis Tomato No. 22, recently introduced to the Market Gardeners. (See page 80.)

Ideal Plant of Summer Pascal Celery
(See page 80.)

The New Poultry Breeding House at Massachusetts Agricultural Experiment Station

The new poultry breeding house, which replaces the one blown down in the hurricane, is 18 feet deep and 126 feet long. There are twenty-four pens, each 5 feet by 14 and capable of taking care of nineteen females and a male, or a total of 480 birds for the house. The house is so arranged that two or four units can be run together. A room 6 feet by 14 at one end of the house, allows some temporary storage of feed, eggs, and equipment, and contains the control of the water supply. A 4-foot-wide service alley runs the length of the house, making it practically impossible for adjoining matings to become mixed. A solid board partition separates the alley from the pens. Each pen contains a wall feed hopper, a droppings pit, and six nests which allows about one nest for each three females. There are joint watering receptacles and drains for each two pens.

The house is insulated mostly with composition board although shavings have been used at the base of all walls under the windows, except in front. Cement floors and foundations and a galvanized rat shield twelve inches high should make the house reasonably rat-proof.

Each pen has a single standard sash for light and ventilation, and there is a 6-inch by 10-foot slot ventilator at the eaves in front for each two pens. This slot is easily controlled by means of an inexpensive adjuster.

Control of Cabbage Maggot. (W. D. Whitcomb, Waltham.) Eggs of the cabbage maggot were first found at Waltham on May 10, which is within the average period for the past eight years. Infestation was slightly greater than normal as indicated by 87 percent commercial damage to untreated cabbage. In spite of favorable growing conditions during May and June, only about one-fourth of the untreated plants developed marketable heads.

Corrosive sublimate solution (1 ounce dissolved in 10 gallons of water) was again the most effective treatment. One application on May 13 gave 98.67 percent commercial protection and produced 87.25 percent marketable heads, while two applications on May 13 and 20 gave 99.33 percent commercial protection with 93.25 percent marketable heads. Root treatments with calomel–talc dusts containing 25 percent calomel or more gave at least 90 percent protection, but dusts containing 10 percent calomel permitted 17.57 percent commercial injury, and a 5 percent calomel dust allowed 38.93 percent moderate or severe infestation. However, plants receiving root treatment with 50 percent calomel or more produced only 57 to 70 percent marketable heads, indicating a delayed growth as well as protection from maggots. In comparison, the plants receiving 5 to 25 percent calomel dust on the roots produced 78 to 80 percent marketable heads in spite of relatively severe damage by maggots. A 50 percent calomel dust with a gypsum carrier gave definitely better maggot protection with a greater yield of marketable cabbage, in spite of apparently poor adhesion when applied, than did a 50 percent calomel–talc dust.

A comparison of the susceptibility of cruciferous vegetables to maggot injury shows the commercial injury as follows: Cauliflower 100 percent; collards 88 percent; cabbage 87 percent; kohl-rabi and broccoli 84 percent; Chinese cabbage 64 percent; and Brussels sprouts 56 percent.

On radishes two dustings with 5 percent calomel–talc dust or sprayings with calomel–gum arabic suspension (1 ounce in 2½ gallons of water) applied 7 and 14 days after the seed was sown increased the average protection against maggots 11 percent in eight plantings from May 1 to July 10. In spite of this protection, 20 percent of the radishes were unmarketable and the treatment does not appear practical. Radishes grown from seed planted without treatment on May 29 and after July 10 had little or no damage from the maggot, while 30 to 60 percent of those planted May 1 to 20 and June 10 to 30 were infested.

Control of Squash Vine Borer. (W. D. Whitcomb, Waltham.) The field infestation by the squash vine borer in unsprayed Hubbard squash in the experimental planting at Waltham in 1939 was 3.24 borers per vine. This is about the average infestation during the last five years. However, favorable growing conditions produced the best yield of squash ever recorded and this yield was not greatly influenced by the borer infestation.

Insecticides were applied on July 6, 13, 20, and 27. Liquid sprays were much more effective than dusts. Nicotine sulfate 1-250 and nicotine sulfate 1-500 plus summer oil emulsion 1 percent reduced the number of borers per vine 74 and 77 percent respectively, while wettable derris spray (4 pounds in 100 gallons) with a resin sticker caused a 35 percent reduction. Derris-clay dust (.75 percent rotenone) failed to reduce the borer infestation, while a commercial copper–rotenone dust (.8 percent rotenone) and a commercial dust containing calcium arsenate, red copper oxide, flour, and talc permitted an increase of 27 and 33 percent in the number of borers per vine.

In spite of the borer infestation, the vines which received dust treatments yielded 10 pounds more marketable squash per vine than those receiving liquid sprays. The best yield (50.64 pounds per vine) was obtained from the vines receiving copper–rotenone dust, while vines receiving nicotine sulfate 1-250 as a spray yielded 35.08 pounds per vine. Increased yields in the dusted rows were apparently due to the beneficial effects of a fungicide in two of the dusts, and to the fact that with favorable growing conditions the damage caused by an infestation averaging about three borers per vine in August does not materially reduce the yield of marketable squash.

Control of Onion Thrips. (A. I. Bourne.) Weather conditions in 1939 were not so favorable for the onion crop as in the previous year. The first part of the season was about 7 to 10 days later than normal. Seed onions were late in appearing and made slow progress during the early summer. Thrips were correspondingly late in making their appearance even on set onions and increased but little throughout June and early July. The drought which persisted from late June until the closing days of July, coupled with the high temperature and frequent hot, drying winds, combined to cause onions, as well as most other field crops, to suffer severely. Unfortunately these conditions were also ideal for the rapid development of thrips, so that by the third week of July the insects were increasing rapidly, and by the end of the month there was one of the heaviest infestations of recent years.

In the experimental plots in early July the plants were only 6 to 8 inches high and showed an average infestation of only 5 to 6 thrips per plant. A 7-day period of extremely hot weather from July 4 to 10 stimulated the development of thrips and more than doubled the infestation. The initial infestation was, however, so low that this increase was not serious although the drought was slowing down the growth of the plants. From July 24 to 29, however, there occurred a second period of abnormally high temperature, and development of thrips reacted quickly to bring the infestation to the peak of its abundance in late July and early August when the plots showed an average infestation of 132 to 134 thrips per plant. This heavy infestation and the continued drought, which persisted with only slight relief until the heavy rain of August 4, caused serious injury to the crop and led to premature death of the plants.

Studies of insecticidal control included field tests of the following sprays: pyrethrum–oil, rotenone–oil, nicotine–oil, derris alone and with talc or cherokee clay as adhesives, a pyrethrum–sulfur mixture, and the standard nicotine sulfate–soap combination. Dust applications were made with pyrethrum–sulfur and with calcium cyanamid.

All sprays containing nicotine or rotenone gave good to excellent control and were noticeably superior to pyrethrum combinations. The effectiveness of derris was somewhat improved by the addition of talc or clay. Derris also showed a marked residual effect which retarded reinfestation. Calcium cyanamid applied as a light dust to plants and soil caused a great reduction in the population of thrips but unfortunately killed the plants. When this material was used in an amount that was nontoxic to the plants, it failed to kill thrips. The nicotine sulfate–soap combination was again superior to all other sprays or dusts used, giving 95 percent effective control, and appears to be the most effective spray for this particular species.

The Spray Residue Problem. (A. I. Bourne.) The drought of midsummer which was not compensated for by the early autumn rains made the spray residue problem a serious one in most orchards, and only by employing a dust schedule or by a strict adherence to the recommended spray schedule with its progressively lighter dosage of lead arsenate in the late sprays was trouble avoided. Increasing abundance of codling moth and apple maggot in late summer made the problem more difficult, in spite of the new limits of tolerance announced in 1938. Records taken at the college showed that the deficiency in precipitation for the months of July, August, and September up to the time the McIntosh crop was harvested was nearly 3½ inches, and from the date of the first cover spray in early June the total precipitation was only slightly greater than the amount of rain in the single storm which preceded the hurricane of September 1938. During the 4-month period there were only 7 records of precipitation of ½ inch or over and most of the rain occurred in light, brief showers which would have little effect upon spray deposits.

The present tendency on the part of commercial growers to replace lime-sulfur with wettable sulfurs led to a study of the effect of such a practice upon the residue problem. Analyses of the residue on fruit sprayed with wettable sulfur showed less than one-half as much lead and less than one-third as much arsenic as was found on fruit sprayed with lime-sulfur. The visible residue persisting on fruit which received some of the wettable sulfurs was evidently misleading, and the margin of safety represented by the difference in the persistence of spray deposit, particularly in a dry season such as 1939, strongly favors the movement toward wettable sulfurs.

Studies of supplementary measures to reinforce the spray schedule and of non-toxic insecticides for codling moth control were continued in the same orchard as in 1938. In addition to banding, a commercial fixed nicotine compound was used in the McIntosh block in late summer sprays to supplement the lead arsenate applications recommended in the regular schedule. Considerably better control of injury by late-season codling moth was secured with the fixed nicotine compound than with the regular spray schedule, shown both in percentages of clean fruit and in percentages of fruit showing late season "stings." The improvement due to the addition of the fixed nicotine compound was even more marked in the drops than in the hand-picked fruit.

The very great reduction in codling moth population was also reflected in band records in this orchard. The total number of larvae collected from 119 trees was 411, or an average of 3.4 per band; in contrast with 1,691 larvae collected from 103 trees in 1937 and 1,184 larvae collected from 93 trees in 1938.

Apple Maggot Control. (A. I. Bourne and W. D. Whitcomb.) The pest was somewhat more abundant than in 1938 and damage was much more prevalent than in 1937. Even the most careful growers throughout the State experienced difficulty in the proper timing of their sprays, and their crop showed more damage than usual. The protracted drought during the period of adult emergence interrupted and delayed the appearance of the flies in some orchards. In more favored locations, emergence was practically normal and the recommended schedule of sprays or dusts gave satisfactory control.

The record of emergence of apple maggot flies from the cages at Waltham is as follows:

	In Sun — Light Soil	
	Cultivated	Sod
1st fly	June 26	July 4
25% emergence	July 7	July 11
50% emergence	July 15	July 14
75% emergence	July 20	July 19
Last fly	Aug. 7	Aug. 1

Insecticides for the Control of European Corn Borer. (A. I. Bourne.) Weather conditions during May were very nearly normal, and on the whole were favorable for the development of both corn and the corn borer. The last frost occurred on May 16, the daily temperature was comparatively high, and from the 20th to the end of the month the minimum temperatures with but few exceptions were 50° F. or above. During that period there was only one storm of any consequence, so that pupation and moth emergence took place normally and there was little or no interference with egg deposition. The month of June was also very nearly normal in both temperature and rainfall. There were light rains well distributed through the month and only three showers of more than one-half inch precipitation. Corn made rapid growth throughout the month, and there was little or no interruption of the spray program.

By the first week of June, egg masses were plentiful and examination of cornfields at the college and vicinity indicated that larvae were beginning to appear on approximately June 8.

Studies of insecticidal control were conducted in cooperation with a commercial market gardener in Hampshire County. The field tests were made in his earliest planting of sweet corn, approximately one-half acre of Golden Early Market. Sprays were applied five times at 5-day intervals from June 8 to 29, to furnish protection throughout the period of larval appearance. An extra application was made to part of the field, at the owner's request, to insure protection against any late-appearing larvae.

The materials tested were derris and cube of 4 percent rotenone content; derris combined with Fluxit or with cherokee clay as adhesives; two commercial sprays, one containing 4 percent rotenone, and the second 2½ percent rotenone. Dual-fixed nicotine and two commercial rotenone dusts were also included in the tests.

The corn was harvested in three pickings from July 19 to 25. The infestation in the unsprayed plots was heavy. Only 23 percent of the ears in the first picking were borer free. The sprays, however, gave excellent protection. The cube and derris plots yielded 81 and 84 percent borer-free ears respectively, and 72 percent of the total yield was marketable. The addition of adhesive agents did not improve derris as measured in terms of clean ears but both materials allowed practically the same percentage of marketable ears as in the plots where derris alone was applied. The commercial 4 percent rotenone spray allowed 72 percent clean ears, and 63 percent of the total yield was of marketable grades. In the plots sprayed with 2.5 percent rotenone, 65 percent of the ears was borer free, and 52.4 percent of the yield was marketable. The total yield in the unsprayed checks was 40 percent borer-free, but only 32 percent of the crop was salable.

Good commercial control was secured in the dust plots. Dual-fixed nicotine allowed 77 percent borer-free ears while the two plots given commercial rotenone dusts showed yields of 71 and 76 percent clean corn. The adjacent check plots on the other hand showed only 40 percent borer-free ears, and only 33 percent of the crop was of salable quality.

The grower was able to salvage a larger proportion of the crop from the treated plots than is indicated above since the market was rather lenient regarding size and development of the ears provided they were free from borers, so that the amount of corn actually marketed by the grower very closely approximated the percentage of clean ears. This was not true of the corn in the unsprayed checks, however, since most of the infested corn contained large, well-matured larvae which had so damaged the ears that they were unfit for market.

Potato Spraying Experiments. (A. I. Bourne.) The subnormal rainfall which persisted throughout the entire growing season retarded the development of potato plants in all sections of the State; was reflected in the relative abundance and activity of insect pests; and, except in low areas, caused somewhat reduced yields. This deficiency in rainfall was accompanied by temperatures considerably higher than normal and by frequent hot, drying winds which rendered the plants very susceptible to spray injury.

Flea beetles were abundant throughout the season, particularly the second brood in late July and early August. Leafhoppers were late in appearing and at no time were abundant. A heavy infestation of potato aphids had developed by early August, but the addition of nicotine sulfate in the sprays of August 9 greatly reduced their numbers and a similar spray on the 15th practically eliminated them.

The experimental plots received 12 applications from June 13 to September 6. There was no evidence of blight, and except in the plots burned by commercial sprays the plants remained green until the crop was dug on October 9 and 10. The first frost occurred October 15, the latest date for this event in the college records. Weekly counts of flea beetle injury showed that there was less damage from flea beetles on plots which had received a 5-2½-50 bordeaux mixture than on those given the standard 5-5-50 strength. The addition of calcium arsenate somewhat reduced the injury in the low-calcium bordeaux plots but gave little or no added benefit in the plots receiving standard-strength bordeaux. In a season of very light and infrequent rains the extra deposit of lime on the foliage was apparently not so essential as in a year of more normal precipitation with frequent, heavy, driving rains. There was, however, greater tendency to burn from the 5-2½-50 bordeaux and this was reflected in the yield records.

Tests of commercial materials were confined to two new materials which were being placed on the market for the first time in 1939: Arsco, a micronized copper–arsenate mixture; and Cuprocide, a newly developed yellow copper oxide spray. Talc and cherokee clay were used as adhesive agents with Cuprocide. Plants sprayed with the yellow copper oxide began to show spray burn by the middle of July, and the damage increased steadily until most of the plants were dead by mid-August.

None of the commercial materials furnished as persistent coverage as bordeaux mixture, or as good protection against damage by flea beetle. Since most of the plants in the yellow copper oxide plots were dead by the end of August, little or no increase in growth of tubers could be expected beyond that point.

The yield from these plots, in view of the abbreviated growing season, would indicate that up to the time the plants died the tubers had made very satisfactory growth, as compared to the rest of the plots, and that, with further improvements by the manufacturers to render yellow copper oxide safer to foliage, the material should prove a valuable spray for potatoes.

Introduction of Parasites of Oriental Fruit Moth in Peach Orchards. (A. I. Bourne.) At the request of the peach growers, the work of rearing and distributing larvae of *Macrocentrus ancylivorus*, parasites of the oriental fruit moth, was continued in 1939. As in the previous year, through the cooperation of the Department of Entomology of the Connecticut Agricultural Experiment Station, Mr. A. DeCaprio directed the collection of breeding material in New Jersey, breeding of the parasites, and delivery to the growers. The breeding work was conducted in the entomological laboratories at the college, and approximately 13,000 *Macrocentrus ancylivorus* were liberated in the orchards of more than 50 growers in 8 counties of the State. *Macrocentrus* parasites in New Jersey were unusually scarce so that it was difficult to secure sufficient breeding material to fill the quota for Massachusetts growers. Our supply, however, was supplemented by material secured through the kindness of Professor Philip Garman of the Connecticut Agricultural Experiment Station, and was just sufficient to fill the orders received.

Weather conditions during the time the parasites were being liberated were favorable for their establishment in the orchards. Because of the dry weather which prevailed throughout late spring and early summer, growth of peach twigs was so much slower than normal that larvae of the oriental fruit moth failed to find the usual amount of succulent, tender twig growth and began in many orchards to enter the young peaches soon after they were formed. When the parasites were liberated, therefore, many of the oriental fruit moth larvae were already inside the fruit and more or less inaccessible. Growers in near-by states where similar weather conditions prevailed had practically the same experience.

Preliminary tests of insecticides for the protection of peaches from late-season infestation were undertaken and some of the fixed nicotine compounds gave promising results.

Naphthalene and Similar Compounds as Greenhouse Fumigants. (W. D. Whitcomb and William Garland, Waltham.) Continued experimental fumigations with chlorinated naphthalene compounds showed that mixtures of chlornaphthalene oil 3 parts and crystal naphthalene 1 part, or chlornaphthalene oil 3 parts and chlornaphthalene soft wax 1 part, were noticeably more effective against red spider on carnation than a mixture containing equal parts of chlornaphthalene oil, crystal naphthalene, and paradichlorobenzene.

The use of these materials, at the rate of ½ ounce per 1000 cubic feet for 6 hours on potted carnations in an experimental fumigation chamber equipped with temperature and humidity control, showed that a temperature of 70° F. with a relative humidity of 60 percent was more effective against red spider than temperatures of 60° F. or 75° F. In twenty fumigations under these conditions the two most effective formulas produced an average kill of red spiders of 98.5 and 99.5 percent in two successive fumigations, with several fumigations causing complete mortality. No injury to potted carnations was observed from any of these experimental fumigations.

Control of the Common Red Spider on Greenhouse Plants. (W. D. Whitcomb, William Garland, and W. E. Tomlinson, Jr., Waltham.) In previous experiments and in commercial greenhouses the common red spider has been more difficult to control on roses than on other greenhouse plants. Observations during November and December under normal greenhouse conditions showed that the average period of development of the common red spider from the hatching of the larva to the adult female was 11.7 days on Talisman rose, 13.8 days on gardenia, and 15.0 days on snapdragon. Similar studies at controlled constant temperatures indicated that at 60° F., 70° F., and 80° F. the spiders required 14.25, 7.71 and 4.77 days respectively on rose, and 18.8, 8.80 and 6.75 days respectively on gardenia. On carnation and snapdragon the development was intermediate to the short period on rose and the long period on gardenia, but there were indications that under some conditions a longer period is required on snapdragon than on gardenia. The development of spiders on ten varieties of roses showed no significant differences when the greatest range was from 6.85 days on Souvenir to 8.0 days on Templar. On Talisman rose, spiders laid an average of 3.49 eggs per female, while on gardenias under identical conditions only 1.2 eggs per female were laid.

In spraying experiments conducted on bench roses under normal greenhouse conditions, derris or cube powder containing 4 percent rotenone, emulsified with sulfonated castor oil 1-300 and diluted at the rate of 2 and 3 pounds in 100 gallons, gave only moderate control of red spider in three applications at weekly intervals but good control after four applications. Derris was slightly more effective than cube but there was no significant difference between 2 pounds and 3 pounds in 100 gallons of spray. Control of red spider was significantly better on Talisman than on Templar, Premiere Supreme, or White Killarney. This spray left a slight residue but caused no plant injury.

In a second series, a dinitro compound prepared experimentally by Dow Chemical Company gave nearly perfect control on all varieties with no serious plant injury. Cyclonox, a phenol preparation, gave good control when used in the first application at 1-400 dilution but was only half as effective after a 1-600 dilution had been used in the three later applications. Plant injury was not serious. R. S. 380, a combination of Lethane and rotenone by Rohm and Haas, diluted 1-400, gave good control of red spider but caused considerable foliage injury at one of the applications. Stantex dispersing oil with rotenone and soap, diluted 1-400, caused severe foliage injury after two applications and its use was discontinued.

In a third series of experimental sprayings, Dow's dinitro compound continued to give excellent control of red spider but caused slight foliage injury. Cyclonox, diluted 1-400 in each of the four applications, was very effective. Some plant injury resulted but none of it was severe or serious. R. S. 380 continued to give good control and was otherwise satisfactory. Bonox, a rotenone material from the Bonide Chemical Company, was not effective when diluted 1-400, and caused slight to moderate plant injury.

A fourth series of experiments showed that Dow's dinitro compound No. 2 with a different spreader continued to cause a high mortality of red spider but produced a moderate amount of injury in the form of marginal leaf burn. A peanut oil–nicotine mixture 1-200 and a peanut oil–rotenone mixture 1-400 both gave moderate kill of red spider but deposited an excessive oil residue on the leaves and caused some defoliation. A Serrid rotenone spray 1-200 was safe on plants but the mortality to red spider was low. Throughout this experiment, the mortality of red spider was greater on the Talisman variety and least on White Killarney.

Biology and Control of the Apple Leaf Curling Midge. (W. D. Whitcomb, Waltham.) The apple leaf curling midge, *Dasyneura mali* Kieff., was normally abundant in 1939 and is not known to have spread greatly from the previously known infested area. A new infestation was recorded in Shirley, Massachusetts, but apparently this had been present for two years.

Semi-weekly examinations from May 26 to October 4 showed that 49.93 percent of the available bud tips were infested with midge eggs. The emergence of flies and deposition of eggs was concentrated at three distinct periods, which indicate the beginning of each generation of the insect: June 1 to 9 with a second peak on June 20; July 7 to 18; and August 15 to 25. During the first infestation period most of the new growth on a tree was infested but after June 20 the infestation was confined to water sprouts which provided the only new growth available.

The time at which midge maggots left the rolled leaves to spin cocoons was considerably influenced by rainfall and was definitely concentrated in three distinct periods. Of the 11,743 maggots collected in bands and cages, 27.51 percent were taken on June 23 and 48.6 percent on August 1. Although only 302 maggots, representing 2.57 percent of the total, were collected on September 5, this was a much larger number than was obtained at any other time after August 8.

Under laboratory conditions no flies emerged in 1939 from maggots collected in June and July 1938 and held over winter, although about 50 percent had failed to transform in 1938. However, 35 to 71 percent of the maggots collected in August 1938 transformed to flies in 1939 after being held over winter under the same conditions as the maggots collected in June and July. In 1939, 68 percent of the maggots collected in June transformed; 52 percent of those collected in July; 21 percent of the August collection; and none of those collected in September.

Soil treatments applied just before the emergence period of the flies indicated that naphthalene flakes were an effective material for this purpose. Broadcast application of these flakes, at the rate of 2 pounds per 100 square feet, was the most effective treatment used and gave complete control in the experiment against the second generation flies. An application of naphthalene flakes at the rate of 1 pound per 100 square feet followed by cultivation was nearly as effective and gave better control than the same amount of naphthalene without cultivation.

Cultivation alone reduced the number of flies 71 percent and 99 percent in first and second generation experiments respectively, and appears to be worth while when insecticides are not applied. Calcium cyanide dust (1 pound per 100 square feet) and carbon disulfide emulsion (1 pint per square foot) were relatively ineffective.

Control of Plum Curculio in Apples. (W. D. Whitcomb, Waltham.) The plum curculio attacked apples at two distinct periods in 1939 and generally caused more damage to fruit than it has for several seasons. In many orchards this insect was the most destructive apple pest of the year. The first critical period occurred on May 31 and June 1, or about three days after the calyx application. At this time, the curculio caused the greatest damage to varieties such as Gravenstein, Astrachan, and Yellow Transparent, which grow rapidly immediately after blossoming. The second critical period continued from June 7 to 14 but was less destructive because adequate protection had been applied.

During the first critical period sprays using lead arsenate 4 pounds, wettable sulfur 4 pounds, and soybean flour 1 pound in each 100 gallons were applied to certain trees June 1, 3, and 6. Just before each application, 50 apples of each variety were measured with calipers to determine the average diameter in sixteenths of an inch.

On McIntosh and Wealthy the examination of about 70,000 apples, including drops, indicated that the spray applied on June 3 when the apples were approximately 4/16-inch in diameter was more timely and effective than the spray on June 1 when the apples were smaller, or on June 6 when they were larger.

Biology and Control of the Grape Plume Moth and Grape Cane Girdler. (W. D. Whitcomb and W. E. Tomlinson, Jr., Waltham.) The Grape Plume Moth, *Oxyptilus periscelidactylus* Fitch, was abundant throughout eastern Massachusetts, especially Metropolitan Boston, in 1939. Examinations of vines in home vineyards near Waltham showed that 32 to 78 percent of the buds were infested.

Laboratory studies proved that this insect has one generation annually. The eggs, which have not been reported in literature heretofore, are laid singly, embedded in the pubescence at a crotch or node on old canes. They are laid in late June and early July, and the average number laid by a female moth in captivity was 12.6. Incubation is completed in about four weeks, but the larva remains in the eggshell until the following spring. The larva hatches about May 10 and feeds for about one month. The pupal period averaged 11.6 days and moths emerged during late June and early July, living seven to twelve days in captivity. The photographs on page 50 show some of the stages of the insect, as well as typical injury to vines.

Dormant sprays applied both in the laboratory and in home vineyards killed the eggs without injury to the vines, and these records are the first known reports of effective control of the grape plume moth with insecticides. The most effective treatments were spraying with sodium dinitro cresylate diluted to 1 and 1½ percent and with oil emulsion (mayonnaise type) diluted to 3 percent. These sprays applied April 21, which was about two weeks before the larvae hatched, reduced the number of infested tips from 55 percent to 2 and 5 percent in one experiment, and from 77 percent to 7 and 19 percent in another experiment.

The results of these studies have been submitted for publication in the *Journal of Economic Entomology.*

The Grape Cane Girdler, *Ampeloglypter ater*, Lec., continued to increase in eastern Massachusetts in 1939 and on some of the infested vines 75 percent of the new canes were girdled.

Life history studies in the insectary showed that there was one generation annually and that the insect hibernates as the adult. Early in June when the grape canes reach 6 to 8 inches in length the beetles begin to lay eggs and continue for about a month. The egg is usually laid in a small cavity eaten in the stem just above a ring of holes which girdle the cane and cause it to break. The girdle cut, which is made by twelve or more punctures in a ring around the stem, apparently serves to eliminate or reduce the pressure of the growing cane so that the larva can hatch and feed more easily.

The life cycle was completed in about 51 days, being divided into 11.6 days for incubation of the egg, 26.8 days for feeding of the larva, and 12.4 days for pupation. The beetles, which emerge early in August, feed slightly on the veins on the under side of the leaf before going into hibernation. In 171 girdled canes examined between June 19 and August 10, 40 percent of the egg punctures were empty or contained dead eggs. Spraying potted grape vines with lead arsenate and calcium arsenate greatly reduced injury by the beetle but did not prevent the canes from being girdled.

Liberation of Parasites of the European Earwig. (W. D. Whitcomb, Waltham.) The European earwig is now established in southern Bristol County, especially in the vicinity of Fall River, Taunton, and New Bedford, where it is a serious annoyance to housekeepers and a minor pest of plants.

In June and July, 1939, 1,000 adult flies of the earwig parasite, *Bigonichaeta setipennis*, were sent in four shipments to Boston by Air Express from the Puyallup, Washington, laboratory of the United States Bureau of Entomology and Plant Quarantine, and were liberated in the infested area. In spite of the long trip by airplane 90.6 percent of these parasitic flies were alive and healthy when released.

Previous to the liberation of the parasites, about forty earwig traps or hiding blocks had been placed at strategic points in the infested area and examined frequently to determine the presence of a suitable number of earwigs for effective parasite establishment. As a result of the trap examinations, parasites were liberated at eleven locations as follows: Fall River 4, Dighton and North Dighton 3, Somerset 2, and Segreganset and Assonet 1 each.

Examinations of the earwig traps for the presence of puparia of the parasitic fly were made on August 16, September 14, October 10, and November 14, 1939. On August 16, 2 puparia of the parasitic fly were found at a liberation point on North Street, Somerset. No other parasites were recovered in any traps at any of the examinations.

Traps will be returned next year to the points where parasites were released, for it is reported that, if the parasites become established, they are more likely to be recovered during the following season than immediately after the flies are released.

Insects Concerned in the Dispersal of Dutch Elm Disease. (W. B. Becker.) An article entitled "Larval development of the native elm bark beetle, *Hylurgopinus rufipes* (Eich.), in Massachusetts" was published in the *Journal of Economic Entomology* 32 (No. 1):112-121, 1939 (Contribution 309).

Mr. W. E. Tomlinson of the Waltham Field Station again cooperated by continuing experiments on the biology of the native elm bark beetle and the smaller European elm bark beetle, in Waltham. The following records were taken.

The Native Elm Bark Beetle, Hylurgopinus rufipes (Eich.). Adults reared from eggs laid in American elm logs in late April and early May of 1938 began to emerge in early August of the same year. No beetles of this brood emerged from these logs during 1939. Since 1934 when the beetle was first studied at Amherst, and during the time it has been studied at Waltham, no adults of the early spring brood have been observed to emerge after the late fall of the same year, although an occasional live larva and young adult of this brood have been found in the logs during the winter.

In logs from trees felled by the hurricane of September 21, 1938, eggs were laid early in June 1939. The adults began to emerge on July 29 and emergence was still being observed on October 18, 1939.

The Smaller European Elm Bark Beetle, Scolytus multistriatus Marsham. The adults reared from eggs laid in elm logs in May 1938 started to emerge in early August of the same season, but many larvae passed the winter in the logs and emerged as adults in June 1939. It is possible that adults that emerged after early August 1939 belonged to the same brood, but it seems likely that they resulted from a later attack on the same logs.

Logs cut in midsummer of 1938 were infested with *S. multistriatus* which passed the winter in the immature stages, the adults emerging during the 1939 season.

In logs from trees felled by the hurricane, eggs were being laid in early June 1939. The adults began to emerge on July 20 and emergence was still being observed on September 10, 1939.

In addition to the biology studies at Waltham, scouting work was carried on in western Massachusetts for *S. multistriatus*. All towns adjacent to those already known to be infested were visited, but the only findings new to this office occurred in two locations in the town of Sheffield where adult beetles were found.

The Effects of Solar Heat on the Subcortical Development of the Native Elm Bark Beetle, Hylurgopinus rufipes (Eich.), at Amherst. (W. B. Becker.) Since it was noticed that *Hylurgopinus rufipes* apparently did not breed successfully in the upper side of small logs of American elm, *Ulmus americana* L., which were in direct sunlight, it was decided to try to get more definite data on this subject.

Elm logs infested with *H. rufipes*, from trees felled during the hurricane of September 21, 1938, were used in the experiment. On July 12 and August 5, 18, and 21, 1939, logs were cut into two equal sections; one section was placed in a large open field where it could receive direct sunlight from sunrise until near sunset, and the other was placed under a tree in the shade of the foliage. All logs were laid directly on the ground, in a north–south direction, and the grass around the logs in the sun was kept short to prevent any possible shading. The logs were put out about 8:30 a. m. and were removed about the same time of day, after different periods of exposure. The beetle mortality in the upper half of the logs in the sun was recorded and checked with the development in the lower half and in the shaded logs.

In the upper half of those logs in the sun, 100 percent mortality occurred in all except one log. This log had relatively thick bark ($\frac{1}{4}$ to $\frac{9}{16}$ inch thick) and had been exposed for only 1 day (8:30 a. m. on August 18 to 8:30 a. m. on August 19). Even in this log, however, only 2 larvae, 1 pupa, and 2 adults were alive, all of them being on the east side of the log only slightly above the line dividing the upper half of the log from the lower half. This is where the sun first strikes the logs in the morning when the temperature of the adjacent environment is cooler than later in the day.

In each case when logs were examined during the subcortical life of *H. rufipes*, specimens were found alive in the under side of the logs in the sun and in any side they happened to infest in the check logs in partial shade. Later such shaded bark also showed the presence of emergence holes, which bore witness to the fact that beetles had completed their development and departed.

In the upper half of the logs in the sun, the larvae killed in 12 or more days beginning July 12 were severely desiccated, indicating that they were killed in less time than that. The degree of desiccation appeared to vary more or less with the length of exposure.

FEED CONTROL SERVICE

Philip H. Smith in Charge

The Feed Control Service comprises not only feed inspection, but several other activities, as listed below:

Feed Control (General Laws, 1920 Chapter 94)
Seed Control (General Laws, 1927 Chapter 94)
Dairy Law (General Laws, 1920 Chapter 94)
Miscellaneous Work

Feed Control. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski, L. V. Crowley, F. A. McLaughlin, J. T. Howard.) During the fiscal year 1,981 samples of feeding stuffs were officially collected and examined in the control laboratories. The gross receipts from the registration of feeding stuffs in 1939 were $24,760, derived from 1,238 brands at $20 each.

Dairy Law. (P. H. Smith, J. T. Howard, G. E. Taylor.) During the year ending December 1, 1939, 6,328 pieces of Babcock glassware were tested; 108 certificates of proficiency were awarded; and 235 creameries, milk depots, and milk inspectors' laboratories were visited in order to check methods and pass upon equipment in use. As a result of this inspection, four machines were condemned.

Miscellaneous Work. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski.) Numerous analyses have been made for residents of the State and other departments of the college.

Summary of Miscellaneous Work, 1939

Milk and cream	727
Ice cream	92
Feeds, from farmers and dealers	87
Feeds, from State Institutions	795
Feeds and forage crops, from Experiment Station	132

FERTILIZER CONTROL SERVICE

H. D. Haskins in Charge

Fertilizer Inspection. (H. D. Haskins, H. R. DeRose, J. W. Kuzmeski, A. F. Spelman, L. V. Crowley, Chemists; J. T. Howard, C. L. Whiting, L. A. Graves, Sampling Agents; G. E. Taylor, Laboratory Assistant.) Records for the year show that 126 firms have registered for sale in the State of Masschusetts 538 brands of mixed fertilizer and fertilizing materials and 52 brands of agricultural lime and gypsum. Results of analysis show that 50 percent of the mixed fertilizer brands, 69 percent of the unmixed fertilizer brands and 85 percent of the lime brands showed no deficiencies. The gross receipts from the registration of the fertilizer and lime products and from fertilizer tonnage fees for the year 1939 were $15,386.76.

For about ten weeks, beginning April 1, three experienced men employed to draw samples for inspection purposes sampled 23,602 sacks or containers, representing 23,020 tons of materials; 173 towns were visited, and 1,818 samples representing 519 brands were drawn from stock found in the possession of 415 agents or owners. The following summary shows the character of these substances, as well as statistics with reference to their inspection.

	Brands Registered	Brands Collected	Samples Drawn	Number of Analyses	Number of Determinations
Mixed fertilizers	340	350	1,100	457	8,143
Ground bone, tankage and fish	44	42	143	45	580
Nitrogen products, mineral and organic	50	48	227	124	536
Phosphoric acid products	34	35	145	38	549
Potash products	16	15	72	23	147
Dried pulverized natural manures	29	29	88	29	292
Nitrate of potash	6	7	11	7	48
Peat products	3	3	6	3	27
Wood and cotton hull ashes	8	7	11	11	83
Miscellaneous	10	10	24	11	122
Lime products	53	52	117	59	1,061
Totals	593	598	1,944	807	11,588

During the period July 1, 1938, to July 1, 1939, the tonnage of fertilizer and plant food sold in Massachusetts was as follows:

	Fertilizer (Tons)	Plant Food Elements (Tons)		
		Nitrogen	Available Phosphoric Acid	Potash
Mixed fertilizers	41,616	2,131	3,529	3,053
Unmixed fertilizer chemicals and materials	20,800*	1,324	1,974**	775
Pulverized natural manures	1,558	33	28	43
Totals	63,974	3,488	5,531	3,871

*Not counting 1,779 tons of triple superphosphate distributed through A. A. A.

**Not including 825 tons of available phosphoric acid distributed through A. A. A.

Full details of the fertilizer and lime inspection will be found in Control Bulletins 100 and 101.

Miscellaneous Analytical and Diagnostic Work. (H. D. Haskins, H. R. DeRose, A. F. Spelman, J. W. Kuzmeski, L. V. Crowley.) Chemical studies have been carried on in cooperation with several departments of the Experiment Station, Field Station, County Agents, and men in charge of the Soil Conservation work of the State. The character and extent of this work is shown in the following summary:

Apple spray residue	32	Peat	4
Cranberry spray residue	5	Poultry manure	15
Fertilizer mixtures	21	Soil	44
Forage and field crops	224	Triple superphosphate (A. A. A. distribution)	39
Grain ration	1		
Insecticide	1		
Limestone (A. A. A. distribution)	22	Total	408

Other work of the department has included consultations on various projects where chemical problems were involved.

Mr. H. R. DeRose has made some vegetation pot studies during the winter and early spring on buckwheat and tomatoes, to note the effect of some of the trace elements on plant growth. The chemical analysis of the crops has not been fully completed.

A considerable variety of chemical work has, as usual, been done for other State Institutions, community organizations, firms and individuals having problems of agricultural interest. This group includes the analyses of the following materials:

Animal tissues for mineral poisons	4
Fertilizer chemicals	10
Industrial by-products	6
Lime products	6
Lime-sulfur	1
Mixed fertilizers	27*
Miscellaneous	8
Peat products	11
Poultry manure	6
Soils	3
Wood ashes	2
Total	84

*Includes 15 private mixtures officially sampled.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (Harold E. White, Waltham.) Field tests for rust reaction and selection of the most promising Field Station strains are being continued. The yellow-flowered lines set seed more readily and abundantly than the white- or pink-flowered strains, and for this reason it has been possible to make a greater number of individual selections of yellow forms. The pink-flowered strains, in addition to being slow growing, are difficult types to true up as to exact shades of color. Pure white flowers, even after continued selection, have a tendency to show a touch of yellow in the palate of the flower. The stem length in most of the strains is satisfactory but further improvement is needed in the size of the individual florets and the length of flower spike. No indication of inherited resistance to the wilt disease has been observed in commercial varieties or in the Field Station strains.

Effect of Plant Nutrients, Soil Reaction, and Light on Gardenias. (Harold E. White, Waltham.) Gardenia plants fed with the same fertilizer mixtures from year to year have varied in their response to such treatments, the number of flowers produced and buds dropped varying according to the fertilizer treatment and seasonal conditions.

Over a period of three years less bud drop was noted with organic materials than with fertilizers carrying ammonium or nitrate salts. Seasonal conditions, however, appeared to have a greater bearing in determining the degree of loss than did the fertilizer treatment. Flower production seemed to be influenced by the same factors which determine bud drop. Gardenia plants did not appear to grow any better in cinders than in soil.

Species of Gardenia plants, grown from seeds obtained from South Africa, seem to be less sensitive than commercial varieties to soil conditions which cause symptoms of iron chlorosis. The species on which observations have been made are: *rothmannia*, *globosa*, *thunbergia*, *jovis-tonantis* and *radicans*. The varieties Belmont, Hadley, Mystery, Veitchi and the species *florida* show susceptibility to iron deficiency.

Forcing Tests of Hybrid Easter Lily Seedlings. (Harold E. White, Waltham.) One hundred bulbs of hybrid lily seedlings grown in Charleston, South Carolina, were received from the United States Horticultural Station at Beltsville, Maryland, for greenhouse forcing tests. The performance of the majority of the seedlings, as regards time required for forcing, number of blooms produced per plant, size and texture of blooms, was comparable with results one might expect to get from bulbs imported from Japan. The results of these tests with American-grown seedling lily bulbs would indicate that the production of such bulbs for greenhouse forcing may become a new horticultural enterprise in this country.

Cultural Requirements of Freesias. (Harold E. White, Waltham.) The practice of drying Freesia corms for a certain period prior to planting, which is considered essential for successful forcing, results in a definite loss in weight dependent on the length of the curing period. The loss in weight varied between 1 and 2 percent for curing periods of 2 to 3 weeks, but after the fourth week increased rapidly. The greatest loss in weight was 31 percent, which was for a curing period of 13 weeks. The loss in weight of corms cured in a potting shed at a temperature of 70° to 75° F. was comparable to that of corms cured at a controlled temperature of 60° to 65° F. Corms cured for 1 to 3 weeks did not appear to make any more rapid vegetative growth than uncured corms. Data on the relation of the length of the curing period to time and degree of flowering are not yet available.

Modification of the growing media by the addition of manure or sand had no noticeable effect on the rate of vegetative growth.

Physiological Disorders of Carnations. (Harold E. White, Waltham.) The sticking and growing together of petals of carnations, a condition commonly known as adhesion, and brought about by some physiological condition of the plant, has been observed to occur sporadically in greenhouses during the past six years. In a number of instances where this physiological disturbance has been encountered, it has seemed to be associated with particular brands of fertilizers applied to the soil. The chief difference between brands of fertilizer that appeared to cause adhesion and brands that did not, seemed to be the high nitrogen content of the mixtures which, under unfavorable light or other growing conditions, were associated with the trouble.

Through the interest and cooperation of a well-known fertilizer manufacturer certain features of a particular fertilizer formula were checked to determine whether any of the materials in the mixture might possibly be the cause of adhesion. Changes made in the original formula were modifications in the ratio of nitrate, ammonia, and organic nitrogen and in the sources of potash. Five different fertilizer combinations were used in the tests. No adhesion was observed with any of the fertilizer mixtures used.

This test does not definitely prove that the fertilizers used may not have been associated with the cause of adhesions, but would rather indicate that there are other factors, such as cultural or seasonal conditions, concerned with this peculiar physiological disorder.

One other trouble with carnations has been observed this past year, in which the nodes or joints of the flower stems were greatly enlarged, causing the stems to grow in a zigzag manner and resulting in a breaking over at the nodes where the swelling occurred. This disorder has so far been confined to certain varieties. It has been suggested that fumigation with naphthalene might be a cause, but this is not definitely known. In all probability this trouble may also be associated with certain nutritional disorders.

Packet Seed Studies. (Clark L. Thayer.) For a fourth season the Department of Floriculture has cooperated with the Seed Laboratory in a test to determine the quality of flower seeds sold in retail seed stores, garages, hardware stores, groceries, schools, and other retail outlets. The seeds, which were collected by the State Seed Inspector, were weighed and analyzed for purity in the laboratory and were tested for germination and performance under field conditions.

The test included 224 lots, representing 42 genera, packeted by 30 wholesale establishments. Records on germination in the field showed 150 lots, good; 38 lots, fair; 31 lots, poor; 5 lots, no germination. Records on performance in the field showed 168 lots, satisfactory; 56 lots, not satisfactory. Detailed results are included in Control Series Bulletin 102.

DEPARTMENT OF HOME ECONOMICS NUTRITION

Helen S. Mitchell in Charge

Cause and Control of Nutritional Cataract. (H. S. Mitchell, G. M. Cook, O. A. Merriam, and A. W. Wertz; Graduate Assistants: Gertrude J. Hadro, Mary D. Henderson.) The study of the biochemistry of cataract continues to be the major project in this department. While the experimental cataract produced by feeding galactose to rats may not be exactly like certain types of human cataract, it is sufficiently similar to justify further study of factors which may hasten or delay its development. In the course of this study unexpected metabolic interrelationships have appeared and where possible these also have been studied in an effort to better understand the influence of other dietary factors upon carbohydrate metabolism. The results of all this animal research may ultimately suggest some clinical applications. This method of producing experimental cataract in rats in a few weeks was discovered in 1935 and has since then served as a unique approach to the study of a little-understood pathologic phenomenon.

1. *The Effect of Nitrogenous Factors on the Cataractogenic Action of Galactose.* Since it has been established by earlier work in this laboratory that a protein deficiency aggravates cataract development, and that a liberal supply delays it, the question naturally arises as to what factor in protein is responsible for this protective action. The relatively minor differences noted between proteins from widely varied sources, mentioned in the last Annual Report, gave almost no clue to the nature of the factor responsible for the inhibition of lenticular change. The observations with cystine previously reported were followed by a limited number of experiments with methionine. Neither of these sulfur-containing amino acids fed as supplements to a 15 percent protein ration afforded protection against cataract commensurate with protection given by adding protein yielding an equivalent amount of these amino acids. The negative results obtained with massive doses of thiamin chloride, riboflavin, yeast, and ascorbic acid, as well as the excellent condition of the animals, offer convincing evidence that no known vitamin deficiency is concerned. Nitrogenous products such as urea and choline have been fed as supplements to the galactose ration with essentially negative results. Work now in progress is concerned with the feeding of proteins treated in various ways which are known to alter the nutritive value of protein for growth. Thus the problem is still unsolved as to why and how protein or some fraction thereof can function to inhibit lenticular changes in rats in the presence of a high blood galactose.

2. *The Effect of Calcium Salts on the Utilization of Lactose.* Considerable variation has been observed in this laboratory in the effect of different calcium salts on the digestion and absorption of lactose. Rats were fed an adequate ration containing 60 percent lactose, plus 1.0 or 0.5 percent of calcium added in the form of six different calcium salts: respectively, tricalcium phosphate, carbonate, citrate, lactate, levulinate, and gluconate. Rats on any of the first five calcium salts showed as good growth as those on the plain 60 percent lactose ration, less diarrhea in general, about the same degree of galactemia, and a similar incidence of cataract. With calcium gluconate fed at the 1.0 percent calcium level, few rats survived; these grew but little, had severe diarrhea, low blood sugar, and no lenticular changes. With 0.5 percent calcium as the gluconate, survival was better, growth poor, diarrhea moderate, lenticular changes few if any. These criteria all indicate that calcium gluconate prevents most of the lactose from leaving the intestinal tract. Since calcium gluconate shows no inhibitory effect upon the absorption of the single sugars, glucose or galactose, the problem must

concern the digestion of lactose. Sodium gluconate, fed at corresponding levels, exerted a similar, but rather more severe, deleterious effect. It would seem that the gluconate radical in some way inhibits lactase activity. The phenomenon known as "competitive inhibition of enzyme action" is postulated as a possible explanation for this finding. A paper on this subject was published in *Journal of Nutrition* 18:319, 1939 (Contribution 347.)

A continuation of this work using both alpha- and beta-lactose fed at a somewhat lower level, 45 instead of 60 percent, confirmed the above findings in general and gave no evidence of any difference in the two forms of lactose.

3. *The Influence of Different Salt Mixtures on the Utilization of Lactose.* Preliminary evidence indicates that the amount and type of mineral elements in a ration may influence the rate of breakdown and absorption of lactose. Two commonly used salt mixtures seem to have slightly different effects. Experiments now in progress are designed to study the effect of the type and amount of salt mixture on the growth, blood sugar, diarrhea, and lenticular changes of rats fed a 60 percent lactose ration.

The Comparative Effects of Kelp, Kelp-ash, and a Synthetic Salt Mixture on Cholesterol-induced Atherosclerosis in Rabbits. (H. S. Mitchell and G. J. Hadro.) A review of the literature shows a growing interest during the last few years in the etiology and therapy of atherosclerosis. A disease similar to that in humans may be induced in rabbits by feeding cholesterol. By this device factors which inhibit this pathologic change may be studied. Since a certain degree of protective action by kelp was shown in previous experiments, it seemed desirable to continue the investigation in an effort to ascertain, if possible, the active principle in the kelp.

In the preliminary experiment one litter confirmed the protective action of the kelp while the other three were less positive in results. The observed correlation between the amount of cholesterol eaten and the degree of lesions necessitated more careful control of cholesterol feeding in subsequent experiments. Another experiment was performed in which kelp, kelp-ash, and a synthetic salt mixture prepared to resemble as nearly as possible the inorganic constituents of kelp were fed to compare the effects of the whole kelp and inorganic constituents of the kelp. About two-thirds of the iodine of the kelp was lost upon ashing. The iodine content of the salt mixture was planned to correlate with that of the kelp.

The salt mixture tended to inhibit hypercholesteremia and protect against aortic lesions as well as the dry kelp and significantly better than the kelp-ash. This indication that no organic factor in kelp is responsible for its beneficial action and previous negative results with potassium iodide alone raise the question as to whether some combination of inorganic elements including iodine is responsible for protection of rabbits against cholesterol-induced atherosclerosis.

The Adaptometer as an Instrument for Detecting Vitamin A Deficiency. (H. S. Mitchell, O. A. Merriam, and E. Miller.) It is generally accepted that vitamin A is necessary for the synthesis of visual purple in the retina. Bright light bleaches visual purple, which is resynthesized when a person adjusts himself to dull light. The rate of adjustment is supposed to correlate with the amount of vitamin A available up to a point of physiological optimum which has not as yet been established. The Adaptometer was designed by J. B. Feldman for making rapid dark adaptation tests on large numbers of persons in order to detect those showing a marked deficiency in this respect. The American Optical Company, who are manufacturing the instrument, provided a research grant to this department for a survey of faculty and students on the campus, and for a study of the limits of accuracy and usefulness of the instrument.

Several technical adjustments were necessary before the survey could be undertaken. Lack of uniformity in instruments was a major problem. The addition of a chin rest, a white visor, and voltage-control were improvements necessary to satisfactory use of the instrument.

The survey of students, faculty, and some other interested persons covered 248 subjects ranging from 5 to 65 years. Of the 163 college students tested only 3 percent gave readings above the normal range (1-5 minutes); of the 75 adults, 18 percent were abnormally high. The self-selection of the adult group, dictated by a personal interest or recognized pathology, may have brought the subnormal average for this group higher than would have been true for a fairer cross-section of society.

The color of eyes was recorded for each subject tested and the data studied to discover whether this factor appeared to have any significance. The percentage falling outside the normal range was slightly higher for the "light eye" group than for the "dark eye" group. The peak for both groups fell at about 1.75 minutes, however, and a relatively small group of stragglers accounted for the subnormal averages.

Seventeen subjects whose time of adaptation was more than five minutes formed a group for further study. Each subject agreed to take three haliver oil capsules daily for 15 days and return for another reading on the adaptometer. Five of the subjects failed to improve, six showed less than one minute improvement and six improved from one to three minutes. The time for more extensive study of these subnormal subjects was limited by the end of the school year.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

W. W. Chenoweth in Charge

Cranberry Research. (C. R. Fellers, A. S. Levine, F. Yourga, and J. Lubitz.) Experimental work has been conducted on several new cranberry by-products such as juice, syrup, relish, and wine. By destroying the natural pectin in raw-pressed cranberry juice by means of the enzyme preparation, Pectinol, the juice may be concentrated and sweetened as much as desired without pectin precipitation. Cranberry relish prepared from sliced cranberries and sugar together with apple or orange can be held for several months in glass jars without heat treatment. Sherry wine and dilute alcohol solutions serve to preserve and flavor the relish for longer periods.

Cooperative research with the Cranberry Station and the Department of Engineering on storage conditions has been continued. Gas analysis of cranberries stored under varying conditions shows that breakdown occurred much more slowly at temperatures below 45° F. than at 55°. There are two types of breakdown or softening: physiological and phytopathological. Both were greatly accelerated by raising the storage temperature. Another aspect of storage work has shown that "floats" from the bogs can be materially improved in keeping quality by prompt drying at low temperatures. Such berries may now be used for shipping as fresh fruit as well as being utilized in manufactured cranberry products.

Some work has been carried out in preparing a "syrup of cranberry" for use as vehicle in compounding drugs and medicines. A very satisfactory syrup was made by cold-pressing the berries and sweetening the juice. Excessive pectin is obtained when the berries are heat extracted. This syrup served as an excellent carrier and masking agent for chloral hydrate, potassium acetate, ammonium chloride, and many other substances.

The tenderizing action of cranberries on meats and fowl has been investigated. Apparently no proteolytic enzymes similar to papain are present. The tenderizing action seems due entirely to the acids present.

An analysis of the pulp or press residue resulting from juice manufacture shows the following percentage composition: moisture 64.0, solids 36.0, ash .30, total acidity 0.23 (as citric acid), pectin 2.9, pH 2.8, together with traces of vitamins A and C. This residue comprises approximately 20 percent of the original weight of the fruit, and is worth saving for use in cranberry sauce manufacture.

A study seeking to ascertain the effect of cranberries on calcium ingestion was completed and the results published in *American Journal of Digestive Diseases* 6 (No. 2):116-119, 1939 (Contribution 321).

Apple Products. (C. R. Fellers and J. A. Clague.) Two products have been studied, canned baked or glazed apples and canned apple slices in syrup. The former study was reported in a paper entitled "Canned Baked Apples," in *Canning Age* 20 (No. 2):68-70, 82 and (No. 4):179-181, 1939 (Contribution 327).

Canned sliced apples in syrup, to be used largely as a dessert fruit, have been prepared in many ways. Best varieties are Baldwin, Winesap, Russet, Northern Spy, Rhode Island Greening, and Spitzenburg. A 40° syrup of either sucrose alone or a mixture of 60 percent sucrose and 40 percent dextrose, gave the most favored degree of sweetness. The cooked slices must be treated under vacuum in order to remove tissue gases and make the slices appear clear and transparent. This product is easily prepared and very acceptable as a fruit dessert. It is not on the market at the present time.

Vitamin D Studies. (C. R. Fellers, C. F. Dunker, and L. R. Parkinson.) Rat bioassays on approximately 162 samples of vitamin D milk produced and sold in New England during the year showed only one sample seriously deficient, and four slightly deficient in content of vitamin D. Irradiated, fortified, and metabolized types of vitamin D milk were examined.

A series of 18 samples of cod liver oil sold for use in poultry rations was bioassayed by the A. O. A. C. chick method. The oils sold in Massachusetts conformed remarkably well to their stated vitamin D guarantees.

As associate referee of the A. O. A. C. committee on Vitamin D Assays, C. R. Fellers has conducted several cooperative tests with rats and chicks in an effort to standardize the vitamin D assay. One result of this cooperative research has been to reduce the period of assay from 10 to 8 days to reduce the number of feedings of Reference Oil from 5 to 3.

In studies on scurvy in guinea pigs, it was found that massive doses of vitamin D in scorbutic guinea pigs did not delay the development of symptoms nor did vitamin D aid in maintaining a normal bone-ash content in these animals.

Antiseptic Action of Acetic Acid. (A. S. Levine.) Investigations have been conducted to determine the effect and action of acetic acid (vinegar) on various food spoilage microorganisms including bacteria, yeasts, and molds. Increasing the hydrogen-ion concentration by the addition of acetic acid lowered the thermal death points of the bacteria studied. Growth of the bacteria was inhibited in nutrient broth adjusted with acetic acid to pH 4.9; the yeast *Saccharomyces cereviseae* (Lister) did not grow at pH 3.9 in dextrose broth with an acetic acid content of 0.59 percent; and growth of the mold, *Aspergillus niger*, was inhibited at pH 4.1 in broth containing 0.27 percent acetic acid. The addition of 5 percent salt or 20 percent sucrose altered but little the toxic effect of acetic acid to bacteria and yeasts. *Aspergillus niger* grown in flasks seemed to utilize the sugar to produce a more luxurious mold growth during the incubation period. The final acidity of the solution was greater than the initial acidity, thus showing a conversion of the sugar into organic acids. Comparison studies showed that acetic acid was more toxic than either lactic or hydrochloric acid to *Salmonella aertrycke*, *Saccharomyces cereviseae*, and *Aspergillus niger*. These organisms were inhibited in growth or destroyed at a higher pH value when acetic acid was used as the toxic agent than when lactic or hydrochloric acid was used. The mold utilized relatively high amounts of lactic acid to develop a luxurious growth heavier than that obtained from the acetic acid or the hydrochloric acid series. The toxicity of acetic acid to various microorganisms is not due to the hydrogen-ion concentration alone, but seems to be a function of the undissociated acetic acid molecule also.

Nutritional Studies on Spinach. (C. R. Fellers and C. F. Dunker.) These studies were reported in a paper entitled "Vitamin C Content of Spinach," published in the *Proceedings of the American Society for Horticultural Science* 36 (1938):500-504, 1939 (Contribution 339).

Factors Influencing Nutritive Value of Snap Beans. (C. R. Fellers and K. T. Farrell.) The vitamin B_1 content of snap beans was 3.5 I. U. per gram, on a moisture-free basis. Freezing apparently had little effect on this vitamin unless the blanching process was omitted, when there was a 40 percent loss. Snap beans canned in glass or tin suffered a 20 percent loss. While frozen blanched beans lost very little vitamin B_1 in 12 months' storage, the canned products showed a 40 percent decrease.

Freezing and canning had little effect on the vitamin B_2 content of snap beans. The average value was 7 Bourquin-Sherman units per gram.

Vitamin C in the fresh snap beans averaged 2.8 I. U. per gram, on a moisture-free basis. A 32 percent loss occurred during freezing, whereas canning resulted in a 75 percent loss. There was no significant loss in the canned or frozen product after 12 months' storage at 45° F.

If the juice from the cans is discarded, 20 to 50 percent of the water-soluble vitamins go with it. The type of container, i. e., glass or tin, showed no marked effect in any of the assays.

Fruit, Vegetable, and Other By-Products. (C. R. Fellers, K. G. Shea, and Wm. B. Esselen.) In order to determine the possible feed value of dried tomato pomace, a waste product from the manufacture of juice and pulp, chemical and biological analyses were made. A report of the work was published in *Poultry Science* 18:45-47, 1939 (Contribution 310).

A study of dried corn distillers grains and concentrated slop was also reported in *Poultry Science* 18:89-95, 1939 (Contribution 311).

Active work now under way indicates that cocoa shell meal is approximately one-third as valuable as cod liver oil as a source of vitamin D for rats. The riboflavin content is also appreciable. It seems possible that this waste product of the cocoa industry may become a useful component of poultry rations.

Food Value of Potatoes. (C. R. Fellers and Mary E. Lyons.) This investigation has been continued and the results published in *American Potato Journal* 16:169-179, 1939 (Contribution 346).

Use of Corn Sugar in Foods. (C. R. Fellers, A. S. Levine, and L. Tarkow.) Results are reported in a paper, "Dextrose in the Food Industries," published in *American Journal of Public Health* 29:135-138, 1939 (Contribution 322).

Iron Availability Investigation. (C. R. Fellers and W. H. Hastings.) The availability of iron in such foods as haddock, peas, asparagus, and broccoli is uninjured by commercial freezing methods. The effect of the canning process is variable, and work is under way to study further the availabity of iron in canned foods.

Glass Container Research. (C. R. Fellers and K. R. Newman.) This study, sponsored by the Glass Container Association of America, has thus far been limited to a determination of head-space and dissolved gases, particularly oxygen, in bottled citrus, apple, and tomato juices. In general, oxygen disappears from bottled juices in 15 to 25 days at room temperatures. Ascorbic acid losses parallel the oxygen loss, indicating a direct oxidation of the former. Coincident with oxygen disappearance is the development of undesirable color and flavor changes in the beverage. The presence of large amounts of oxygen in the head space intensifies and accelerates flavor and color defects. Methods of oxygen removal at the time of filling the containers are now being studied.

DEPARTMENT OF HORTICULTURE

R. A. Van Meter in Charge

Powdery Mildew on Garden Phlox. (Harold S. Tiffany, Waltham.) Preliminary tests were conducted for the control of powdery mildew (*Erysiphe cichoracearum*) on garden phlox (*Phlox paniculata*), from the standpoint of plant tolerance and residue as well as disease control. No plants were sprayed until an appreciable amount of the mildew was evident throughout the plantings. Materials for control were then applied at ten-day intervals up to the flowering period.

Hammond's Copper Solution (1-150) resulted in fairly complete control and left no residue on the plants. Bordeaux mixture (2-2-50) gave equally good control but left objectionable residue. Neither of the other materials tested gave satisfactory control.

Propagation of Hybrid Lilacs. (Harold S. Tiffany, Waltham.) Late taking of lilac cuttings has been widely believed to offer a very low percentage of rooting. Four hundred internodal lilac cuttings (*Syringa vulgaris*, varieties Souvenir de Ludwig Spaeth, Marceau, Congo, Charles the Tenth, Jan Van Tol) were taken on July first, a full month after the wood was in prime condition for taking. Forty cuttings of each variety were given a constant temperature of 75° F. by electric cable, and forty were kept at room temperature of the benches. Each forty cuttings of the same variety were further divided into tens, receiving (a) Hormodin powder No. 3; (b) Rootone; (c) Hormodin A (60 BTI units for 24 hours); (d) no treatment. Five of each ten cuttings were terminal, and five had terminals removed, to test the theory that terminal leaves transfer a higher percentage of growth substances to the base of the cuttings than do other leaves. The cuttings were all placed in a medium of one-third peat and two-thirds sand; cheesecloth tents were provided; and the cuttings were watered fairly heavily.

Varietal response to the various treatments was pronounced. While bottom heat at 75° F. definitely hastened rooting of some varieties this effect was not consistent with others. Treatment with a growth substance was effective with some varieties; others rooted better with no treatment. At the end of thirteen weeks, 53 percent of the cuttings had produced good and excellent root masses. The ratio of terminal cuttings rooted was one-third higher than of those without terminals. With the exception of six plants lost, the potted plants produced excellent root systems and strong winter buds. Further trials will be made in 1940.

Factors Influencing the Rapidity of the Growth of Nursery Stock. (Harold S. Tiffany, Waltham.) The fertilization of evergreens, in order to provide maximum quality growth, represents a problem on which comparatively little research has been done. In view of the importance of such material to ornamental plantings, investigations have been started by the establishment of fourteen plots of Carolina Hemlock (*Tsuga caroliniana*), ten trees to the plot, which will receive different treatments in 1940.

Factors Influencing the Hardiness of Evergreens. (Harold S. Tiffany, Waltham.) Winter injury to evergreens is a serious problem both in nurseries and in ornamental plantings, particularly of those species which are injured at infrequent intervals only, and at such times to an extreme degree. Cultural treatment seems to be one of the factors involved. Accordingly three plots of the spreading English Yew, *Taxus baccata repandans*, have been started as suitable material for study, since the species *baccata* is outstanding in the list of plants affected. By 1940 the plants should be sufficiently established to allow the beginning of the treatments to be tested.

DEPARTMENT OF OLERICULTURE

Grant B. Snyder in Charge

Shape Index Studies of Tomatoes. (W. H. Lachman.) It has been demonstrated in past years that shape indices are quite reliable in making quantitative comparisons among varieties of tomatoes. These studies have been continued with the idea of ascertaining the influence of season upon the form of fruit in several tomato varieties. Under unfavorable growing conditions the polar diameter of the fruit is greater in proportion to the equatorial diameter than under more desirable conditions.

Sweet Corn Breeding. (W. H. Lachman.) This project was initiated three years ago in an effort to isolate inbred strains of sweet corn which excelled in earliness, productivity, disease resistance, and quality. More than 1600 plants of eight early commercial varieties were self-pollinated and have since been carried in pedigreed lines. From this early work 300 lines have been selected as the best of the progenies.

The planting has been made on the same plot each year. The soil in this plot is evidently thoroughly contaminated with root, stalk, and ear-rot diseases of corn. In addition to this, each plant has been inoculated with the bacterial wilt disease. Approximately 200 of the lines show a moderate to high degree of resistance to all of these diseases. Most inbreds of Golden Gem, however, seem to be particularly susceptible.

Many of the lines showed a remarkable degree of uniformity the past year and will be combined in the hybrid condition to further test their usefulness.

Hybrid Sweet Corn Trials. (W. H. Lachman.) Thirty-five hybrid varieties of yellow sweet corn were planted for trial during the past season. Many of these performed very well but were a little too late in maturity for general usefulness in Massachusetts. Four of the varieties were especially noteworthy: Spancross C4.13, which was exceptionally early; Marcross C13.6, an early sort with an ear of good size; Marcross 13.39, a second early with an ear of good size and exceptional quality; and Golden Cross Bantam, a midseason variety with a large ear, high productivity, and excellent quality.

Tomato Breeding. (W. H. Lachman.) The primary object of this project is to incorporate the uniform ripening character into otherwise desirable commercial tomato varieties. Most commercial varieties of tomatoes have a green to yellow-red coloration of the shoulders when firm ripe. This character is undesirable from the market viewpoint.

By cross-pollinating a variety of little importance possessing the uniform ripening character with six commercial varieties of tomatoes, many promising segregates have been noted and selected for further study. Although the work has progressed to only the third generation, several lines appeared to be quite uniform during the past growing season.

Cultural Practices Prior to Field Setting as Influencing Yield and Quality of Peppers. (W. H. Lachman.) This project was started last year in an effort to determine the effect that different methods of handling plants prior to field setting might have upon the earliness, yield, and quality of the fruits produced. The Waltham Beauty strain of pepper has been used throughout the test.

Plants grown in clay pots until time for field transplanting consistently outyielded plants receiving all other treatments. Nutrient solutions at the rate of one pint per plant added at the time of field transplanting markedly increased both the early and total yield with all the basic treatments.

Variety Studies. (W. H. Lachman.) These studies were begun last year in cooperation with the Rhode Island and Connecticut Experiment Stations. The object of the work is to determine the influence of the various climatic and edaphic factors upon the general adaptability of several strains and varieties of snap beans, celery, cabbage, tomatoes, peppers, and sweet corn. It is planned to continue this project for five years, and as yet no general conclusions have been drawn.

Asparagus Investigations. (Robert E. Young, Waltham.)

Varietal Improvement. The most important information obtained from a study of the field records of 278 selected asparagus plants is that the high-yielding plants selected as parents for new strains have continued to remain high yielding throughout seven cutting seasons. A paper by G. C. Hanna of the California Agricultural Experiment Station indicates that asparagus plants may yield heavily the first few years only to become mediocre later. Only one of the parents of the five new strains of asparagus now under culture at Waltham has shown any tendency to fall off in yield.

In 1937, five rows of asparagus plants from the selected parents were planted. These plants produced a larger number of stalks during the first summer than in either of the two succeeding years. The number of stalks per plant was reduced considerably this past year, probably because of their being harvested and of the extremely dry season. While these plants were cut for only two weeks for the first harvest, the records give some indication of which rows are superior. Rows 1 and 4 have produced a large number of spears per plant. During the past three summers, they also produced the largest number of stalks per plant during the summer season. The rows that produced the largest number of spears per plant also had the highest yield in pounds per plant. All the rows of the new asparagus planting gave better yields than a commercial strain planted for comparison, the two best strains producing over twice as much.

Of the best twelve plants out of 450, selected on the basis of the number of spears produced, four were female and eight were male. When ranked on the basis of weight, nine were female and three were male. Most of these high-yielding plants were from the two highest-yielding strains.

Depth of Planting and Height of Cutting. The yield of the depth-of-planting plots returned to normal this year after having been very low the previous season. There has been no change in the relationship of the yields; the plots where the roots were planted 2 inches deep gave the best yields, followed respectively by those planted 4 inches, 8 inches, and 6 inches. This rank is in direct relationship to the number of plants remaining in the plots except for those where the roots were planted 8 inches deep.

In October of 1939 the asparagus tops were removed and the land leveled. After a period during which the soil settled, the asparagus crowns were examined and their depth determined. Roots originally planted 2 inches deep were found to vary from 2 to 7 inches, with an average depth of 3.6 inches. Roots originally planted 4 inches deep were found to vary as did those planted 2 inches, the average depth being 4.5 inches. The average depth of roots planted 6 and 8 inches deep was 3.9 and 4.5 inches respectively. While there are some differences in the average levels, it might be said that all the asparagus plants formed at the level they preferred for the soil in which they were planted, which is a Merrimac fine sandy loam underlaid with coarse gravel. The information concerning the levels to which asparagus crowns grow, together with yields and stand counts, is being prepared for presentation before the American Society for Horticultural Science.

The height-of-cutting records continue to show that when asparagus tips are cut the yield will be less than when spears are cut with 8 inches of green. Almost 35 percent more 4-inch spears per plant have been produced than 8-inch, but the yield in pounds is much less for the nine years the plots have been harvested. Cutting spears with 12 inches of green has not reduced the yield in pounds of asparagus although it reduces the number of spears.

It would seem from the results of this experiment that the best returns from an asparagus bed can be obtained by cutting the spears with 8 inches of green. However, there seems to be no danger of injuring the bed by producing long asparagus, even up to 12 inches.

It appears from the two sets of asparagus records that have been kept for seven and nine full cuttings seasons that the peak of production comes in the third year.

Trellis Tomato Experiments. (Robert E. Young and Paul W. Dempsey, Waltham; Alden P. Tuttle, Amherst.) This past season was a very dry one, and it is of interest to note that pruning tomatoes to a single stem increased the percentage of cracking of fruit. The plot that had potted plants pruned to a single stem produced the largest early yield and the greatest total yield. The plots that produced notably low yields were those without fertilizer, those with plants not trellised, and those without manure. The plants not pruned or trellised produced only one-third the early yield of the best trellised plot. These untrellised plants produced fruit that had the least cracking. Additional irrigation also greatly reduced cracking. The work on trellised tomatoes has been concluded.

Vegetable Breeding for Improvement of Quality. (Robert E. Young, Waltham.)

Lettuce, New York Type. (In cooperation with United States Department of Agriculture.) Approximately 10,000 plants were grown last season in the search for a better adapted lettuce. Of these plants, the four single-plant selections made from a new hybrid were outstanding for heading, color, and resistance to tipburn. These new types are hybrids similar to the Cosberg, which is a light yellow variety, except that they are dark green in color and produce a better head.

During the past season the aster yellows disease was quite severe and widespread, affecting lettuce all over the northeastern United States. In other seasons from 10 to 25 percent of the selected plants have become infected with aster yellows and have been lost, since the diseased plants do not produce seed. This past year approximately 85 percent of the selected plants became infected with the disease, thus causing a loss of the most important breeding stock. Whether the increase in the extent of the disease is due to weather, or is a natural increase which will persist in future years, remains to be determined. Certainly some method of protection must be found if a breeding program is to continue.

The selections that have been grown for a number of seasons continue to be superior to commercial varieties. However, they are susceptible to the same trouble as the commercial varieties but to a lesser degree.

Greenhouse Lettuce. The first generation of a cross between Bel-May and Cheshunt Giant was produced in the greenhouse. Although both of these varieties of lettuce contain no pigment, all the hybrids had spots of red pigment on the leaves. This is an undesirable character. However, according to a study of the genetic behavior of pigments in lettuce by R. C. Thompson of the United States Department of Agriculture, this character will not remain in future generations. The second generation was produced in the fall of 1939 and only a small percentage was pigmented. In this cross between a light green lettuce and a dark one, the F_2 generation produced 50 light green and 164 dark green plants. The other desirable characters were also redistributed in a desirable way that will enable the best plants to be selected in very few generations.

Celery. The growers who tried samples of Summer Pascal celery seed distributed last year gave most favorable comments and the celery met with almost state-wide favor. The most impressive demonstration of the desirability of a product that has high quality is the fact that during a season of unusually low prices Summer Pascal celery sold for at least twice the price of yellow celery. One grower reported selling three hundred dollars worth of celery from the teaspoonful of seed sent out as a sample. Seed of this variety has been made available commercially and will be grown extensively next year. It is a celery that under some conditions is more difficult to grow, but the high quality justifies the extra care. Summer Pascal celery seed was obtained from a grower in another section of the country who had kept it within the family for over forty years. It is not a perfected strain and many single-plant selections have been made in an attempt to purify it. Experiments attempting to force the plants to seed in the greenhouse during the winter in time for next year's crop have failed. This work is being continued and plants have also been sent to the Federal Experimental Station in Puerto Rico in an attempt to speed up the seeding of these plants.

Variety trials with over thirty varieties of green celery were made for the second year. The results of this work indicate that most of the varieties will not bleach with sufficient ease for local conditions. Many of the varieties have stalks so rough as to be unmarketable on the Boston market.

Tomatoes. Waltham Forcing and Field Station No. 22 have become widely used as trellis tomatoes. The Early Trellis which was distributed last year proved to be too small to be of value. It is of great interest to note that most of the Massachusetts growers who had both Waltham Forcing and No. 22 reported that the latter produced larger fruit. Growers in the section around Lowell, however, reported the reverse to be true. At the Field Station it required 4.6 fruits to make one pound of the Waltham Forcing tomatoes, and 3.6 fruits of the No. 22.

For the past few years selection work has been under way to improve the internal quality of the Waltham Forcing. After this year's crop, it was concluded that the particular undesirable characteristics could not be eliminated by selection. A new program of hybridization will be undertaken to improve the quality of these tomatoes. The hybrid material that has been made in the past and has been under trial will be kept.

A comparison of Waltham Forcing and No. 22 with other strains of Comet in the variety trials indicates that their most outstanding characteristics are heavy setting of fruit, a large percentage of No. 1 fruit, and an outer cell wall that is resistant to bruising and keeps the tomato in a firm condition long after many varieties have become unsalable.

Waltham Forcing, which was originally developed for use in the greenhouse, maintains its popularity.

Rutabaga or Cape Turnips. Two years' trials of all the available varieties and strains of Rutabagas, both white and yellow fleshed, which could be obtained in this country and abroad have shown that if a perfected strain is to be developed it must come from material already locally adapted. Strains grown locally, though reported faulty, are better than those obtainable elsewhere. The results with single-plant selections indicate that large numbers must be used if the breeding program is to go forward. A large number of selections is now in storage, and with the varieties no longer in the plantings more space and time can be devoted to breeding work.

The yellow sport from a strain of White Cape mentioned in last year's report has been further tested and found to be a very desirable type, having the same characteristics as the White Cape except the flesh color. Crisp flesh free from fiber and with not too much turnip flavor is what makes the strain desirable.

Cucurbita Pepo. The work with this crop has been completed with the development of a uniform strain in plant type, shape of fruit, and condition of seed.

Hutchinson Carrot. The work with this crop is conducted in two ways. The most important part is the maintenance of the strain and replenishing the supply of stock seed. Through rigid selection of the stock seed roots, a gradual improvement in the color of the carrots has been noted by growers. Particular attention has been given to internal color. The old Hutchinson had a large yellow core. The Field Station strain now has a medium-sized core of quite good color.

The second phase of the work with carrots is the hybridization of Hutchinson with other carrots of better internal quality. A carrot obtained from the Bureau of Foreign Plant Introduction of the United States Department of Agriculture has been used as one parent in these crosses. Methods have been developed that will permit the production of carrot seed from selected roots in the greenhouse in time for planting the next year, thus making an annual out of the biennial carrot. The F_2 generation of these better quality hybrids was grown this year and a large number of very good selections has been made.

Waltham Beauty Pepper. The work of developing a better adapted pepper has been continued this year with thirty selections from hybrids in which one parent was Waltham Beauty. These hybrids are now in the third and fourth generation. Very few plants have been found that contain the desirable characteristics of the Waltham Beauty without poor ones. The amount of cross-pollination in peppers in this section has not been determined. No bags have been used to prevent cross-pollination. This year the selected plants were moved to the greenhouse where a new crop of fruit is being produced under conditions that make cross-pollination impossible. A comparison will be made of the self-pollinated seed with that raised in the field.

Green Sprouting Broccoli. At the request of many growers, over 40 varieties and strains of green sprouting broccoli were collected this past year, from this country and abroad. These were grown in the hope of finding a more uniform strain of this vegetable that is becoming more popular each year. No strain was found to be particularly better than another. There is a variation of over a month between the harvest of the early plants and that of the late ones in the same strain. Selected plants have been saved and are being seeded in the greenhouse for planting next year in hope of obtaining a strain more uniform in maturity and type of head.

Wyman Crosby Beet. This strain of beet that has been developed from the strain of one of the local growers will be sent out to selected growers for trial on their farms. If it proves to be superior, it will be increased for future use. It has been found that to obtain much improvement in the internal color of beets it is necessary to use single-plant selections instead of mass selection. Several plants have been seeded in the greenhouse and were planted this last year in the field. Further selection has been made from these for next year's trials.

Horticultural Shell Beans. Work with shell beans is being concluded with this year's work. A good strain of shell bean has deen developed and is being used by many farmers. Wider use of the bean has been prevented by a lack of commercial supply of seed. One association has tried six times to have a crop grown for them with failure in all cases. Seed for distribution to farmers who wish to get a stock of the bean will be maintained.

Greenhouse Cucumbers. Some time has been devoted during the last year to the gathering of strains of greenhouse cucumbers prior to starting breeding work. All the strains were planted outside and were self-pollinated to purify them. Further purifying must be done before hybridization can be accomplished.

DEPARTMENT OF POMOLOGY

R. A. Van Meter in Charge

The effects of the hurricane of September 21, 1938, on our orchards were not as injurious as was feared by some. The trees, not too badly torn up or broken, were set up and held by guy wires and very few of them have, thus far, shown injury. The crop produced was the heaviest since 1930. It remains to be seen whether the root damage followed by a heavy crop will weaken the trees in future years. Apple trees bloomed heavily and the fruit set well. Rainfall was somewhat deficient during the season but there was enough in late summer and early fall to favor good size of the apples.

Fruits other than the apple were fair to good except raspberries. The canes suffered severely from winterkilling. Peach buds survived the winter and trees that were healthy bore good crops. The severe cold in late November was unprecedented. No colder weather was experienced through the winter. This early winter cold may have been the cause of injury to raspberry canes and nursery apple trees.

The Influence of Various Clonal Rootstocks on Apple Varieties. (J. K. Shaw and L. Southwick.) The stock bed yielded a fair crop of rooted layers which were lined out for budding. They made a fair growth in spite of the rather dry season. It has been observed that any variety grows about equally well on all stocks the first year. This may be because the root system of a very dwarfing stock is enough to promote good growth of the single bud. In the second and third year dwarfing effects may be seen with some varieties and stocks, but in many cases vigorous growth continues until the tree begins to bear at an early age for the variety. Growth in height is retarded before growth in spread, giving a rather low-headed tree. The type of the root system is largely controlled by the rootstock, but its size is determined by the variety budded on it.

Preparations have been made to set another stock bed next spring to replace the present one, which is not as productive of rooted layers as it should be.

Some additions were made to the cooperative orchards and all have been visited and measurements taken. Many made very little growth, probably owing to the dry season. These were the ones in sod. It becomes increasingly evident that it is very difficult to grow a young orchard in sod. Either cultivation or an adequate mulch is essential.

Starking on Malling XIII and XVI, set at the Waltham Field Station on a rich, moist, loamy soil in 1936, blossomed and bore heavily. Other varieties in the same orchard blossomed lightly or not at all.

The new orchard mentioned last year was set in the spring of 1939. It includes 900 trees of many varieties, old and new, on the various clonal stocks. The tree locations are randomized according to the latest ideas of such plantings. It is laid out so as to permit some cultural or fertilizer test which will be started after a period of uniform treatment to give more light on soil variations. A smaller orchard of 55 trees was also set to replace one ruined by the hurricane.

The clonal stock orchard set in 1937 grew well irrespective of the rootstock, and some trees, mostly on the dwarfing stocks, bore a few apples. It promises to produce more next year, the fourth year of growth.

The older clonal stock orchard set in 1928 produced a large crop. The trees, McIntosh and Wealthy set 20 x 20, after eleven seasons' growth, are becoming crowded and showing signs of inadequate nutrition. Three reports of results from this orchard are included in the scientific contributions from this Station.

Tree Characters of Fruit Varieties. (J. K. Shaw, A. P. French, O. C. Roberts, and L. Southwick.) Practically the same nurseries as in recent years were visited and trees examined for trueness to name. A slightly greater number of apple trees was certified than in 1938.

The stand of cherry buds in the nursery was again poor but at least a few buds of most varieties grew and afforded an opportunity to learn their distinguishing characteristics. The stocks on which the buds failed were cut back and shoots allowed to grow up to four per plant and these budded usually to two buds each. With this excess of inserted buds, it is hoped to get a satisfactory stand of all varieties and collect data and photographs for a publication on cherry varieties. It is believed that all these varieties that are really distinct can be identified as nursery trees.

The peach nursery of some 60 varieties grew well and afforded opportunity to collect a considerable amount of data. Most varieties can be identified with considerable certainty, but there are a few groups of varieties which are so nearly alike as to make certain identification of individual varieties impossible. The varieties have been budded on additional stocks for further study next year.

Further observations of pear and plum varieties have indicated that there are certain varieties of these fruits that require careful study, so a small nursery of such varieties is planned for next year.

The Genetic Composition of Peaches. (J. S. Bailey and A. P. French.) In the spring of 1939 some crossing and selfing was done. Although they had been recorded as free from X-disease in 1938, five of the nine trees used developed X-disease before the summer was over. It is probable that the pits from these diseased trees will not germinate.

A campaign was started to eliminate all chokecherries from around the Station and College orchards. Various concentrations of a chlorate weed killer were used to find out how the work can be most effectively and cheaply done.

In the fall of 1939 peach seedling block S^2, M, N, and the budded seedlings were removed since they were no longer needed for record purposes. The men of the Experiment Station service developed a very rapid and effective method for pushing the trees out of the ground and shaking the dirt from the roots by chaining them to the bulldozer attachment of a caterpiller type tractor.

Calculations on a second population of selfed Belle seedlings agree with previous results in that they show linkage in the coupling phase between the free–cling and the melting–nonmelting genes.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw.) The changes in fertilizer treatment made last year were continued in 1939. The orchard bore a crop of nearly 1400 bushels or approximately 20 bushels per tree, which was by far the largest thus far produced. The attempt to harrow in the mulch applied last year to plot 3 was not very successful because the soil was very compact and the mulch less decayed than expected. A second application of waste hay, about two tons per acre, was made, and the trees bore the most heavily of any in the orchard even though the trees, after 18 years of cultivation with no fertilizer, were the smallest of any. This astonishing increase in yield over previous years is probably not due entirely to the mulch, as all our McIntosh trees bore heavily this year, but it is believed that the yield was larger than it would have been if no mulch had been applied. This suggests that the use of mulching materials in amounts much smaller than were used in our other experiments may be a wise practice. For many reasons we confidently advise the use of mulching materials brought in from outside the orchard whenever they can be obtained at a reasonable cost.

Comparison of Cultivation and Heavy Mulching for Apples. (J. K. Shaw.) The McIntosh block in this experiment was removed in the spring of 1939 on account of severe damage from the hurricane which blew over in varying degrees 13 of the 18 trees. The area was at once replanted with trees largely Wagener and Rhode Island Greening on clonal stocks. No additional mulch was applied as it was felt that there was an ample amount already. The mulching will be continued as seems wise. The young trees behaved alike on both the mulched and cultivated plots, none making good growth perhaps because of injury to the pith and xylem from winter cold while the trees were in the nursery. The Wealthy block suffered little from the storm and is being continued as before.

The Effects of Fertilizer Limitation on Fruit Plants. (J. K. Shaw.) Some of the trees have been removed and the rest will be pulled out next spring because they are getting too large for the limited area. The fertilizer applications on this field—nitrogen, phosphorus, and potash, alone and in combination—have now been continued with few changes for 50 years. There are no differences in available phosphorus in the soil between the plots that have had continuous phosphate applications and those that have had none. The differences in available potash and nitrogen are not consistent.

Effect of Potash and Lime on Apple Trees. (J. K. Shaw.) The effort to invigorate the trees in this orchard by strip cultivation was continued and the fertilizer treatment remained the same. The trees seem to be responding and a heavy crop was produced. The nitrogen-fertilized trees continued to yield far better than those receiving only phosphorus and potash. The addition of potash to nitrogen seems to have slightly increased yields but the difference this year was insignificant.

Study of Varieties of Fruits. (J. K. Shaw and staff.)

Apple. Observations in the nurseries show that the so-called red bud sports of many varieties continue to replace the varieties from which they sprung. Probably this tendency means improvement, but in many cases the parent varieties, when well grown, may be quite as attractive as the new ones—but they are not always well grown. Occasional comments suggesting inferiority of the sporting variety in vigor, productiveness, and other characters are not yet supported by experimental evidence. This question will be investigated in another project at this Station. Some of the red sports of Gravenstein seem to keep better than Gravenstein. This may or may not be an advantage.

Cortland seems to be gaining in favor but cannot yet be said to be a major variety in this State. It seems to be more susceptible to internal cork than other varieties but it appears that this can be controlled. It is a favorite variety of the curculio. It is susceptible to storage scald, and must be picked at the proper stage of maturity. In our experiments this has been about two weeks after McIntosh. The variety has met with sales resistance in the market, but this is being overcome by advertising and by its many good qualities. We would rather take a chance with Cortland than with McIntosh after Christmas. It is excellent for kitchen use, especially salads, as it does not turn brown. The tree is very satisfactory, hardy, mechanically strong, has a strong tendency to annual bearing, and it is a good pollinating variety. It should be regarded as a replacement of Baldwin rather than of McIntosh. Perhaps it should not be planted extensively, but we regard it as one of the most promising varieties to supplement McIntosh.

Kendall is still on trial, with little evidence of its value here. Its greenish flesh is the defect most often mentioned. It is said that this will be less evident if the apples are allowed to mature well on the tree. The apple is attractive in shape and color but the quality seems inferior to McIntosh and Cortland. We have as yet little evidence on the very important character of productiveness.

Early McIntosh meets with considerable approval from growers. It is attractive, of good quality for its season, and its name attracts customers. On the other hand, the tree habit is poor, it is strongly biennial, and the apples are apt to be small unless heavily thinned. There is room for something better for its season.

Milton is of the same season and a better variety in tree habit and in quality. Were it not for its peculiarity of bearing apples of unattractive shape, it should be preferred to Early McIntosh. Perhaps as trees get older the shape of the apple will improve.

A bud sport of Gravenstein from a Lunenburg orchard bore very attractive apples that may prove equal or superior to the strain now in cultivation.

An orchard of several hundred seedlings, grown from seeds obtained in cross-pollination experiments several years ago, fruited quite generally. Among them were several that were promising. More careful observations in later years may possibly reveal some trees that are worthy of propagation and further trial.

Pear. Gorham continues to prove desirable, being attractive and of good quality. It resembles Bartlett and is about two weeks later in season.

Phelps is also of the Bartlett type but later in season. It is of good size but unattractive in appearance and of inferior quality.

Peach. The New Jersey Station continues to breed many excellent new varieties. Some will prove desirable for Massachusetts, but some will be less successful here because of lack of bud hardiness. Golden Globe (N. J. 73) is a competitor of Halehaven, maturing about a week later than Golden Jubilee. It seems rather tender in tree and bud and not as good in quality as when grown in New Jersey. Goldeneast (N. J. 87) is another New Jersey variety which does not reach as high perfection here as in New Jersey, but it is a little more promising than Golden Globe. Fire glow (N. J. 71) is also better in New Jersey than here. It is so tender in bud that it is likely to be an uncertain cropper in Massachusetts. Eclipse competes with Goldeneast and Halehaven and it seems probable that this older introduction will lose out in the competition.

Halehaven replaces South Haven, an earlier production from Michigan, and all agree that it is an improvement. It ripens between Golden Jubilee and Elberta and is worth trying. Polly closely resembles Champion and therefore has no place except for strictly local trade. We have no evidence as to whether it is superior to Champion.

Some of the peach trees grown for variety study in the nursery will be used to establish a new variety peach orchard to be planted next spring. This should give us much additional first-hand information about varieties.

Raspberry. Marcy continues to perform well and has not yet shown mosaic infection. The berries are large, attractive and of good quality. It is a good producer and superior to Taylor in quality. Our Taylor plants now show 100 percent mosaic infection; in Newburgh the percentage is much lower. No roguing has been done in these rows.

All Geneva introductions have been quite severely killed back the past two winters, while Latham and Chief have shown little or no such injury.

Strawberry. Pathfinder (N. J. 35) has proved to be attractive, of good shape, juicy, of fair quality and a good producer. North Star (U. S. D. A. 1425) is large, of attractive appearance, of high quality and satisfactory in productiveness.

Fruit Bud Formation in the Strawberry. (R. A. Van Meter.) Continuing a study of the relation of mulching to winter injury and the behavior of fruit buds, 30 plots of 180 plants each were established in the spring of 1938 and harvested in 1939. The thickness of the mulch had a direct bearing on the amount of winter injury but the time of mulch removal needs further study as it may affect the behavior of fruit buds as reflected in yield.

To complete this study 20 plots of 300 plants each were planted in the spring of 1939. These were given four treatments in five replications, as follows:

1. Light mulch to be removed early.
2. Light mulch to be removed late.
3. Heavy mulch to be removed early.
4. Heavy mulch to be removed late.

Observation of the effect of these treatments on yields next season should bring this phase of the study to an end.

Bud Mutations. (J. K. Shaw and W. H. Thies.) Among the many scions collected several years ago in the belief or hope that they were bud sports, is one that has possibilities. This is a highly colored Gravenstein that seems equal and may prove superior to the Red Gravenstein now grown. Most others have proved little or not at all better than the parent variety.

The collection of possible bud mutations of the McIntosh has been carried on and 20 different lots are now budded in the nursery. Not all of these are thought to be improvements on the variety as commonly grown, but most of them are of higher color as indicated by the fruit of the trees from which they came. These trees will be grown and fruited to see, not only whether they have superior color, but whether they are in other respects equal or superior to the variety as commonly grown.

It was observed that the buds of one strain started a little later and did not grow quite as tall as did those of three other strains. This observation requires confirmation before it can be said that the strain is really less vigorous than the others.

Gas Storage of Strawberries and Apples. (O. C. Roberts.) During the past season a study of the effect of CO_2 on the storage of strawberries, raspberries, and apples has been made. The work this year has been of a preliminary nature and has consisted chiefly in a study of technique and general observations. Conclusive results have not yet been attained.

Study of Behavior in Storage of Apples Affected with Internal Cork. (O. C. Roberts.) It is generally recognized that certain varieties of apples grown in soils deficient in boron will in dry seasons develop internal cork or corky core. Some growers have expressed the opinion that this condition may disappear to a greater or less extent in storage. In order to obtain exact data on this problem, samples of apples, known to be affected with internal cork, were collected from orchards in Middlesex County and brought to Amherst. On September 26 random samples were selected from these lots and examined for amount of internal cork present. The remaining apples were divided into two lots, one of which was placed in common storage and the other in cold storage at 32° F. On November 26 samples from these two lots were examined, and the remaining apples left in storage for further examination in January 1940. Results to date show that in both common and cold storage there was an increase in the percentage of apples with medium and heavy amounts of internal cork. The trend seems to be toward an increase in the amount of this trouble in storage rather than a decrease. (See photograph on page 53.)

Tests of Spray Materials. (O. C. Roberts.) In accordance with a practice which was adopted several years ago, the Departments of Pomology, Entomology, and Botany cooperated in the testing of new spray materials and combinations. Detailed results of the work done this year will be found in the report of the Entomology Department.

Nutrition of the Highbush Blueberry, Especially in Relation to Soil Reaction. (J. S. Bailey.) In the fall of 1938 a number of blueberry plants were removed from the nursery, put in Wagener pots, and placed in a storage cellar where the temperature remained just above freezing. Starting on the fourth of January three plants were moved weekly to a warm greenhouse to see how soon the rest period of blueberries is over. The first plants brought in required nearly four weeks before any activity was indicated by a swelling of the buds, and nearly another four weeks before the plants were in bloom. The plants brought in January 30 required about two weeks to show signs of activity and about three more weeks to come into bloom. The plants brought in the third of March showed signs of activity in 5 days and in 19 more days were in bloom. The last plants brought in were in bloom in 24 days as compared with 54 days for the first ones.

The plants used in the experiment above were obtained from a nursery where no evidences of iron chlorosis had ever been observed. They were potted in soil from the nursery. In the greenhouse they were given a liberal supply of a complete fertilizer, watered plentifully, and the temperature, although fluctuating considerably, averaged rather high. This treatment caused the plants to make a very rapid growth, and several of them developed iron chlorosis. This indicates that some soils might be unsuitable for blueberry growing if the plants are forced to grow too rapidly.

Blueberry plants were sprayed with 8 percent solutions of each of the following: ferrous sulfate, ferric chloride, soluble ferric phosphate, and ferric sulfate. These sprays all reduced the chlorosis, but all caused more or less leaf burning.

Blueberry Culture. (J. S. Bailey.) Two plants of the Wareham variety in blueberry plot C appear to have a new blueberry trouble discovered in New Jersey by R. B. Wilcox. The symptoms are a shortening of the internodes and a dwarfing and reddish discoloration of the leaves. The whole plant is dwarfed. The cause of this trouble is unknown.

Because of the warm, wet fall and the sudden drop in temperature to −4° F. on November 26, 1938, there was considerable winter injury to blueberries. The variety Cabot was injured much worse than any other. Plants of this variety bore an exceedingly light crop in 1939.

Italian rye grass was tried as a cover crop for blueberries. It was planted about August 15, when the picking season was nearly over, and made a very good growth before cold weather. Since the fall was late and warm, this cover crop probably made a better growth than could be expected in most years. Although it grew very well on soil with a pH of 5.2, it made practically no growth on soil at 4.5. Therefore, it is doubtful if this cover crop will ever prove generally useful for blueberries.

Since the 1939 season was a dry one, the berries were considerably smaller than normal. Winter injury and the dry season reduced the crop about 50 percent.

Buds of two new U. S. D. A. seedlings, GN-45 and GN-87, were obtained from New Jersey by permission of Dr. George M. Darrow of the U. S. D. A. They were budded into several bushes in row A, blueberry plot C. Buds of the U. S. D. A. seedling FI-66, which we have had for several years, and of the variety Dixi, were budded into bushes in this same row to increase the supply of propagating wood.

In the fall of 1939 an experiment was started in blueberry plot D to try a combination of mulching and cultivation. Various mulches, such as sawdust and waste hay are being used in the rows under the plants. The space between the rows will be cultivated.

In the spring of 1939 nine plants of a new seedling, No. 73, were planted in blueberry plot B.

In the spring of 1939 all of the blueberry plants in blueberry plot A were removed with the exception of a few diseased bushes. These diseased bushes will be retained for a short time for further observation.

On June 22 two blueberry plants each of the varieties Rubel, Cabot, and Pioneer were heavily dusted with sulfur at 3 p. m. when the sun was bright and the temperature 80° F. On July 7 there was no sign of injury on any of the plants. At 4 p. m. on that day, which was slightly cloudy, with a temperature of 92° F., these plants were redusted. By July 10 the two Pioneer plants showed severe burning along the edges of the leaves on some of the branches. The other varieties showed no injury at that time or later in the season.

About 350 bushes were removed from the east and south side of blueberry plot D in the spring of 1939. This was done for two reasons: (1) to reduce the size of the planting and thereby reduce the cost of maintenance, and (2) to remove the blueberry bushes from parts of the field not well suited to blueberry growing.

Premature Dropping of the McIntosh Apple. (L. Southwick.) Further evidence of the significance of seeds in influencing premature drop of McIntosh apples was obtained. Using the total crops of two trees, correlation coefficients above +.500 indicate considerable association between the number of seeds in an apple and its date of drop and suggest the importance of adequate cross pollination for McIntosh.

Pollen from seven varieties was used on a tented McIntosh tree to check on pollination success. The results indicate that of the varieties commonly considered good pollinators for McIntosh, some are better than others based on the seed counts in this experiment. In general, the severity of pre-harvest dropping seemed to vary with the variety of pollen used on the basis of the number of seeds which developed.

Limb injections of chemical nutrients gave further evidence that abundant nitrogen in the tree tissues hastens McIntosh fruit drop. The mean date of drop of a nitrogen (urea) injected limb was advanced fully four days ahead of similar untreated limbs or limbs injected with non-nitrogenous materials. A potassium sulfate injected limb likewise dropped its fruit relatively early but this probably was due in part at least to rather severe leaf injury. In another single tree test, both the nitrogen injected limbs and the potassium–phosphorus injected limbs dropped their fruit a little earlier on the average than similar untreated branches. However, the differences here were small and conceivably may have been due to the injection procedure itself rather than to the particular materials used. All of these preliminary results are suggestive only, as the data are few and present only one year's observations.

Some McIntosh trees in the Station blocks showed a peculiarly large amount of leaf browning early in September which was followed by severe pre-harvest fruit drop. Potassium tests made on leaf petioles showed plenty of this element present. A very limited chemical analysis showed a relatively high percentage of total nitrogen in the fruiting spurs on these trees.

Much of these new data seems to support the evidence from field experiments previously reported, that a high state of fertility, especially in relation to nitrogen, tends to increase pre-harvest fruit dropping.

A so-called growth substance, alpha naphthylacetamide, was used to test its effect on delaying normal McIntosh drop. On September 13, 200 gallons of a .00025 percent solution of the chemical in water were made up in a spray tank and the spray applied to alternate trees in two blocks at the usual pressures (300-400 lbs.). The results were largely inconclusive, although in several cases the evidence pointed to a beneficial effect. It is possible that different concentrations and times of application may prove to be of significance. Further work is planned for next year. (See photograph on page 53.)

Sun Coloring of Apples. (O. C. Roberts.) McIntosh apples with 0 to 10 percent color were placed in a frame covered with three layers of cheesecloth on September 13. They were removed from the frame after exposure to approximately 80 hours of bright sunshine and were not turned during exposure. When gathered the average color had increased to approximately 60 percent. None of the apples showed sun scald. The quality of the color was duller and somewhat less attractive than on apples which were allowed to color normally.

Ten bushels of Wealthy apples, selected at time of picking for lack of coloration, were spread on a hay mulch underneath a Wealthy tree with dense foliage. After ten days the color had increased from less than 5 percent to more than 50 percent on the surfaces exposed to this indirect light. The under-surfaces did not show any color changes. The flesh texture became noticeably less firm but not enough to adversely affect market value.

DEPARTMENT OF POULTRY HUSBANDRY

R. T. Parkhurst in Charge

Broodiness in Poultry. (F. A. Hays.) This project has three primary objectives: (1) To secure more data on the inheritance of degrees of broodiness, (2) To study the phases of deferred broodiness, (3) To determine whether a genetically non-broody line of Rhode Island Reds is possible.

The generation hatched in 1938 completed its first laying year in November 1939. This generation came from two sires that were 36 months of age and one sire that was 24 months of age in 1938. The matings gave 38 daughters with complete trapnest records from nine non-broody dams. No daughters gave any manifestation of broodiness in the first laying year. A considerable number of these daughters is being retained for a trapnest record during the second laying year to check on deferred broodiness. Males are constantly being checked genetically for the presence or absence of genes for broodiness.

A Genetic Study of Rhode Island Red Color. (F. A. Hays.) A line of birds from an exhibition foundation is being carried forward to study the genetic relationships between plumage color and characters affecting fecundity. The stock is now in the eleventh generation. The data suggest that there may be certain adverse physiological relationships between genes for exhibition color and genes for high fecundity. Data are also being secured on the mode of inheritance of exhibition plumage color.

Rate of Feathering in Rhode Island Reds. (F. A. Hays.) Early feathering in Rhode Island Reds may be measured by the development of complete back feathering in males at eight weeks of age. Females in this breed are for the most part well feathered over the back at eight weeks or younger.

Two lines are being developed from the standpoint of dorsal feather growth, and are now in the sixth generation. One line is selectively bred by using sires that have shown complete back feathering; the other has been developed by using sires that have lacked back feathering at eight weeks of age.

A total of 155 cockerels was produced from two sires in the early-feathered line. The first sire gave 69 percent early-feathered sons, and 18 percent of his sons showed tail development at 12 days of age; 12 percent of his daughters had tail development at 12 days. The second sire in this line gave 63 percent early-feathered sons and 26 percent of his sons showed tail development at 12 days; 51 percent of his daughters had tail development at 12 days. The 155 males in the early-feathered line gave 65 percent early feathered, and about 24 percent had tail development at 12 days. The development of back feathering was not closely related to the development of tail growth at 12 days, the latter apparently being due to the sex-linked gene reported by Warren in Leghorns. In the early line there were four families in which all males had complete back feathering.

The late line consisted of 36 males and 32 females from five different families, all sired by one late-feathered male. These males showed 100 percent late feathering at 12 days and at 8 weeks of age. The females also showed 100 percent late feathering at 12 days.

The data so far collected seem to indicate that early feathering in the dorsal region in males is due to several recessive autosomal genes and that a sex-linked recessive need not be present to produce the desired phenotype. Barred Plymouth Rock chicks in the Station flock show a high degree of back feathering but not a single individual has shown tail development at 12 days.

The Effectiveness of Selective Breeding to Reduce Mortality in Rhode Island Reds. (F. A. Hays.) Cooperative project with Regional Poultry Research Laboratory, East Lansing, Michigan. Two lines are being developed by selective breeding: one selected for low mortality in the laying houses and the other for high mortality in the laying houses. Selection of breeding stock to reproduce these two lines is based entirely upon mortality rates with no consideration given to fecundity characters or to egg characters. The fifth generation, hatched in 1938, has completed a full laying year.

In the low mortality line 49 pullets were placed in the laying houses and 20 individuals died, giving a mortality rate of 40.82 percent. Eleven birds died from cannibalism, six from undetermined causes and one each from ruptured yolks, tumors, and prolapsus of the oviduct. The death rate was excessive because of the high incidence of cannibalism.

In the high mortality line 43 pullets were housed. The loss in the first laying year was 25 birds, giving a mortality rate of 58.14 percent. Seven birds died from cannibalism, 12 from undetermined causes, 3 from ruptured yolks, 1 from a cholera-like disorder, and 1 from prolapsus of the oviduct. In this line there was one pullet that survived but never laid and another that laid but 36 eggs.

The sixth generation was hatched in 1939. In the low mortality line 135 chicks were hatched, and the mortality to six months of age from all causes was 6.6 percent. In the high mortality line there were 153 chicks, with a mortality rate of 10.46 percent for the first six months. There was one case of neurolymphomatosis.

In the low mortality line 45 pullets were placed in the laying houses and 41 cockerels were retained. These represent complete families. To December 1, 1939, 2 pullets have died from cannibalism and none from diseases or disorders, and no cockerels have died. In the high mortality line 46 pullets were housed and 47 cockerels were retained, all representing complete families. No losses of pullets or cockerels have occurred to December 1, 1939.

Genetic Laws Covering the Inheritance of High Fecundity in Domestic Fowl (F. A. Hays and Ruby Sanborn.) Major objectives in this project are: (1) developing a line that is genetically pure for sexual maturity at 180 to 215 days, (2) fixing high intensity so that the winter clutch size will exceed 3, (3) eliminating all inherited winter pause, (4) eliminating the broody instinct, and (5) fixing genetically high persistency. In addition to the above characters, studies are also being made on fertility, hatchability, chick feathering, body weight, egg weight, plumage color, comb type, shank feathering, and inherited factors affecting mortality rate.

Mortality rate in the laying house was higher in the 1938 flock than in the three previous flocks, largely because of the paralysis complex of diseases. Special selective breeding to avoid the paralysis complex was used to produce the flock hatched in 1939. Up to December 1, 1939, no paralysis has occurred in this generation.

Experimental crosses with outside stock are being made to check the genetic behavior of characters being studied. The experimental line started in 1913 is also being maintained.

During the year, Bulletins 359 and 365 have been published on this project, and Bulletin 307 has been enlarged and revised.

A Study of Fertility Cycles in Males. (F. A. Hays.) This project began in the late summer of 1939. Material is now being collected for studying the stages of spermatogenesis in males of various ages through the winter season.

Physiological Relationships Between Molting Behavior and Fecundity Characters. (F. A. Hays.) Biweekly observations on the molting behavior of a group of exhibition and production Rhode Island Red males and females was begun July 27, 1939. These and previous observations will serve as a guide to the first breeding phase to be undertaken in the spring of 1940.

The Technique of Testing Vitamin D Carriers with Chicks. (A. O. A. C. method). (R. T. Parkhurst.) Tests are being made of the vitamin D potency of various cod liver oils, sardine oils, fortified cod liver oils, and fortified sardine oils in cooperation with the Feed Control Service and the Nutrition Laboratory. Future work will include other types of carriers. A real need for authentic information regarding claimed potencies is indicated.

SEED CONTROL SERVICE

Philip H. Smith in Charge

Seed Inspection. (F. A. McLaughlin and Jessie L. Anderson.) From December 1, 1938, to December 1, 1939, the Seed Laboratory received and worked 2663 samples of seed, of which 1003 were collected by the State Commissioner of Agriculture and 1661 were sent in by seedsmen, farmers, and various state institutions. An additional lot of 224 samples of flower seeds, for field tests only, was also received from the State Commissioner of Agriculture.

Classification of these samples with the total number of laboratory tests involved is shown in the following summary. It will be noted that the total number of tests required for the 2663 samples was 3763; 857 for purity and 2906 for germination.

Samples		Purity	Germination
644	Field Crops for Purity and Germination	644	644
14	Field Crops for Purity Only	14	...
123	Field Crops for Germination Only	...	123
103	Lawn and other types of Mixtures for Purity Germinations involving 456 ingredients	103	456
96	Lawn Mixtures for Purity Only	96	...
1501	Vegetable Seeds for Germination Only	...	1501
37	Flower Seeds for Germination Only	...	37
22	Tree Seeds for Germination Only	...	22
123	Tobacco Seeds for Germination Only	...	123
2663		857	2906

Field tests to determine trueness to type were conducted in cooperation with the Departments of Vegetable Gardening, Floriculture, and Agronomy, which tested respectively, 193 samples of Vegetable seeds, 224 samples of Flower seeds, 20 samples of Oats, and 73 samples of Corn. All samples for these tests were collected and submitted by the State Commissioner of Agriculture, with the exception of 4 samples of Oats, which were sent in by seedsmen.

The Seed Laboratory cleaned 7 lots of Onion seed and 73 lots of Tobacco seed for Connecticut Valley farmers.

Corn, oats, barley, and wheat purchased by various State institutions (179 samples) were examined for conformity to grade purchased; and 103 samples of ground cattle and poultry feed, collected by inspectors or sent in by dealers and farmers, were examined microscopically.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Control Service. (H. Van Roekel, K. L. Bullis, O. S. Flint, and M. K. Clarke.)

1. *Pullorum Disease Eradication.* During the 1938-39 season 365 flocks (including 10 flocks other than chickens) were tested. A total of 623,935 tests (including 3,565 paratyphoid tests) was made on blood samples received from 12 counties. Norfolk, Worcester, and Middlesex Counties led in the number of birds tested. The average percentage of reactors was 0.34, which is a slight increase over the previous season. The increase in reactors is due to the detection of infected birds in one large flock which had no infection the preceding season. Reactors were detected in all of the more common breeds of chickens. No infection, either pullorum or paratyphoid, was found in fowl other than chickens.

A total of 298 non-reacting flocks (100 percent tested, representing 440,689 birds) was identified. The value of these birds is expressed by the increased egg production, increased fertility and hatchability, and high chick livability which represent an inestimable monetary saving to the poultry industry of this and other states of this country.

Infection was discovered in 10 flocks which were negative the previous season. The source of the infection was determined in some of these flocks. It may be concluded from these "breaks" in negative flocks that annual testing of all birds on the premises, plus effective precautionary measures against the introduction of infection, is necessary to keep the spread of pullorum disease at a minimum.

The growing interest in pullorum disease eradication in Massachusetts for the 1938-39 season is manifest by increases in tested flocks (47), tested birds (90,838), tests (117,436), and non-reacting flocks (41).

During the past year this department has continued to cooperate with the Massachusetts Department of Agriculture by making available testing results which are used for official recognition and classification of pullorum tested flocks.

2. *Diagnostic Service.* A total of 751 consignments, which included 3,682 specimens, was received during the past year,—an increase of 91 consignments and 1,065 specimens over the previous season. Personal delivery of specimens was made in 465 cases. The classification of the specimens is as follows:

Bovine	2	Goose	1
Bovine liver	1	Guinea fowl	1
Bovine semen	4	Guinea pigs	4
Calf	1	Mink	8
Canary	1	Mink feces	2
Canine	2	Pheasants	43
Canine feces	91	Pigeon	1
Canine skin scrapings	1	Quail	3
Chickens	3,054	Rabbits	3
Duck	4	Ruffed grouse	2
Feed	2	Sheep	2
Feline	4	Swan	1
Foxes	3	Swine	11
Fox lung	1	Swine liver	1
Goat feces	1	Turkeys	427
		Total	3,682

Disease conditions noted most frequently in the chickens were coccidiosis, tumors, fowl paralysis, pullorum disease, and infectious bronchitis. Fowl cholera was identified in 16 cases, 9 of which represent new known foci of infection. Fowl typhoid was noted in 11 cases. These diseases can no longer be considered rare, although fowl typhoid infection in particular seems to be limited to small areas within the State. Avian tuberculosis was observed in birds from three premises.

The increased interest and expansion in turkey raising in Massachusetts have resulted in a considerable increase in the number of diseased turkey specimens for the diagnostic service. A comparison of the number of consignments and the number of turkey specimens for the past five years is presented below:

	1934–35	1935–36	1936–37	1937–38	1938–39
Cases	17	28	26	44	71
Specimens	84	145	184	172	427

The more important and the more frequently occurring diseases noted in the turkey specimens are listed in the following five-year comparative summary:

	1934-35	1935-36	1936-37	1937-38	1938-39	Total
Coccidiosis		4	4	8	5	21
Enterohepatitis	6	6	3	9	7	31
Fowl pox				3	2	5
Fowl typhoid	1		1		4	6
Moniliasis				1	3	4
Paratyphoid	1	2	3	2	16	24
Perosis	6	1	1	1	1	10
Pullorum disease		4	1	3	9	17
Rickets	1	3	3	3		10
Staphylococcosis			2		1	3
Swine erysipelas		2	1		2	5
Ulcerative enteritis		4	4	3	2	13

3. *Pasteurella and Pasteurella-like Cultures* (*Avian Origin*). Some physiological characteristics and the pathogenicity of 61 such cultures were examined. The typical Pasteurella cultures fermented mannite, produced indol, and were pathogenic for rabbits, while the Pasteurella-like cultures were mannite- and indol-negative and non-pathogenic for rabbits. Strains of the latter group did, however, produce a disease condition in chickens which was represented largely by inflammation and pus formation in the tissues in the region of the tibio-metatarsal joints. Because of difficulties encountered in routine work in obtaining satisfactory growth in carbohydrate media with *Pasteurella* cultures, 23 media were tested. A medium containing 1.0 percent peptone, 0.3 percent meat extract, 0.5 percent sodium chloride, and 1.0 percent of the desired carbohydrate was the most satisfactory.

4. *Avian Encephalomyelitis.* Investigations concerning avian encephalomyelitis ("epidemic tremor") have revealed that the disease is becoming a more serious problem to the hatchery and baby chick industries. Field and laboratory findings strongly suggest that the infective agent is transmitted through the egg from the hen to the progeny. Transmission in the incubator through direct contact is also suspected because the disease has spread among chicks through direct contact during the brooder stage.

The infective agent has been passed through 92 serial passages in chicks. Strain differences in susceptibility were observed among experimental chicks. Turkey poults and ducklings were found to be susceptible to the disease upon inoculation. White mice, rabbits, guinea pigs, mature pheasants, and sparrows were found to be refractory.

A more detailed report of these investigations was published in *Veterinary Medicine* 34 (No. 12):754, 1939 (Contribution 355).

5. *Equine Encephalomyelitis Virus* (*Eastern Type*). During the past year a strain of equine encephalomyelitis virus (eastern type) was isolated from a pheasant brain which was received from Dr. F. R. Beaudette, New Jersey Agricultural Experiment Station. This observation was made at the same time other investigators discovered this infection among pheasants and pigeons in Connecticut and Massachusetts. These findings represent the first definite isolation of the infective agent from naturally infected wild birds. Host susceptibility experiments revealed that the English sparrow and purple grackle can be added to the list of susceptible hosts, including man. The results of these investigations were published in the *Journal of American Veterinary Medical Association* 94 (n. s. 47):466-468, 1939 (Contribution 344).

6. *Viability of S. pullorum.* Viability studies, which are still in progress, show that *S. pullorum* has remained alive in a dry piece of cloth for a period of seven years. The remarkable ability of a vegetative organism of the nature of *S. pullorum* to remain viable over such a long period may give an insight into some of the practical eradication and prevention problems of pullorum disease.

7. *Pullorum Disease in Turkeys.* A study of pullorum reacting turkeys for a period of approximately 18 months (including two laying seasons) has revealed that the causative agent (*S. pullorum*) may be eliminated through the egg in two successive laying seasons. Repeated agglutination tests, using the macroscopic tube method, disclosed that infected turkeys may exhibit a variety of titres. Among the 19 turkeys necropsied during the course of the experiment, *S. pullorum* was isolated from five. The agglutination titres of these five infected turkeys at the time of necropsy were 1:10, 1:20, 1:40, 1:40, 1:640. Two of the infected birds previously had exhibited a titre of less than 1:10. These observations should have a significant influence in combating the spread of pullorum infection among turkeys and other poultry.

8. *Farm Department Brucellosis Control and Eradication.* The laboratory cooperated in this work by testing the following blood samples for Brucella infection: 674 bovine, 60 porcine, and 1 equine. The standard tube agglutination method was used.

Studies of Neoplastic and Neoplastic-like Diseases. (Carl Olson, Jr.) The transmissible lymphoid tumor of the chicken whose origin was described in a previous Annual Report (for Year Ending November 30, 1938) has been carried through 39 serial passages. No change in the type of disease produced has been observed. Successful transmission of the disease has apparently been dependent upon the presence of living cells in the material used for transplantation. In some instances whole blood of birds with the tumor has been used successfully as an inoculum. Attempts to obtain an active extract from the tumor tissue have thus far been negative. Regression of the transplant after a period of active growth was noted in some chickens and further inoculations of transplants in these chickens have failed to grow. Transplants of the tumor did not grow in new sites in chickens in which growth of a previous transplant had become well established. Transplants of the tumor grew readily, however, in chickens spontaneously affected with fowl paralysis. This would seem to indicate a difference in the pathological lymphoid tissue concerned in these two diseases.

Attempts have been made to transmit experimentally other spontaneous cases of neoplastic disease (some similar to the above and others dissimilar) and some spontaneous cases of fowl paralysis. To date such transmission has not been observed.

Nearly 300 instances of spontaneous neoplastic disease have been collected among chickens derived from various sources. This material is being studied to determine the relative incidence as well as the characteristics of the various types of neoplasia.

Observations on the antigenic properties of chicken erythrocytes have been made during the past three years. Previous work by other investigators has indicated that the individual components of the antigen mosaic of the chicken erythrocyte are for the most part inherited as dominant properties, although there are some whose presence indicates a complicated inheritance. This phase of work was entered upon as an adjunct to the inbreeding of a group of chickens for the purpose of securing experimental stock of relatively similar genetic constitution. For the purpose of studying the blood cells of these chickens the method of Landsteiner and Levine (*Soc. Expt. Biol. and Med. Proc.* 30:209-212, 1932-33) was followed. In this method advantage is taken of the ability of serum of normal cattle to agglutinate erythrocytes of chicken blood. By cross absorption tests the erythrocytes of individuals of a group of chickens may be shown to have a different antigenic structure. Differences in the agglutinating ability of serums from different cattle were found and in this work serum from the same cow was used in the successive tests.

The group of chickens upon which these observations were made included an original lot of inbred birds and two succeeding generations of progeny from this original lot. The original group of 21 birds were brothers and sisters. They had only five individuals for great-grandparents instead of a possible eight; two of the grandparents were brother and sister and two others were sired by the same male (half brother and sister). The two succeeding generations from this stock have resulted from the mating of brother and sister. Three groups or types of erythrocytes have been classified in these chickens by the method employed. Group I erythrocytes are characterized by the ability to remove all agglutinating power of the particular cow serum used in these tests for erythrocytes of other chickens in this family. Group II erythrocytes have the ability to remove the agglutinating ability of the cow serum for only the erythrocytes of the same group, that is Group II. Group III erythrocytes have the ability to remove the agglutination power of the cow serum for erythrocytes of Group III and Group II, but do not affect the ability of the serum to agglutinate Group I erythrocytes. The classification of the erythrocytes of the parents of the original group of chickens is not known. Of the original group, six chickens (28.6 percent) had erythrocytes belonging to Group I, four chickens (19.0 percent) had erythrocytes belonging to Group II, and eleven chickens (52.4 percent) had erythrocytes belonging to Group III. The next generation was from a male having erythrocytes of Group I and a female with Group II erythrocytes. Most of the progeny of this mating had Group III erythrocytes, (17 chickens—94.5 percent) and one only had Group I erythrocytes. It is probable that some with Group II erythrocytes might have been found had more progeny of this mating been tested. The third generation tested was from a mating of a male and female both of which had Group III erythrocytes. Of those tested, nine (24.3 percent) were Group I, twelve (32.4 percent) were Group II, and sixteen (43.3 percent) were Group III. A complicated system of inheritance of erythrocyte type is suggested by the presence of Group I erythrocytes in the progeny where both male and female have only Group III erythrocytes.

WALTHAM FIELD STATION

(Waltham, Massachusetts)

Ray M. Koon in Charge

The members of the research staff of the Waltham Field Station are assigned to the unit by the Departments of Botany, Entomology, Floriculture, Horticulture, and Vegetable Gardening. Reports of these departments give results of investigations conducted at this branch station.

Consultation and Information Service. A definite increase was noted in the number of commercial vegetable growers, orchardists, florists, nurserymen, arborists, professional gardeners, greenkeepers, and amateurs who came to the Field Station this year to personally consult members of the staff. Many of these organizations now hold meetings at the Station at irregular intervals, and the Executive Committee of the Boston Market Gardeners Association meet regularly once a month.

Evaluation Gardens. In a garden of 1500 species and varieties of herbaceous ornamentals, all have been rigorously discarded which fail to qualify as hardy, or are otherwise unsatisfactory in the latitude of Massachusetts. This has resulted in a collection of real importance to nurserymen and landscape and amateur gardeners. The value of such a collection, well grown and accurately labeled, is evidenced by visits from over 3000 persons during the flowering season.

Field Day. Perfect weather brought out 1250, a record attendance for the twenty-first annual Field Day on August 2. Considered from all angles, it was the most successful Field Day conducted by the Field Station. Exhibitors report greatly increased interest on the part of the visitors in the mechanical equipment they display. Interest in the celery contest was especially keen this year as the new Summer Pascal variety was exhibited for the first time by local growers.

Soil Testing Service. The demand for the soil testing service is increasing and it is believed that the interpretation of the tests will contribute to a better understanding of some of our soil fertility problems.

Massachusetts Nurseryman. Reports of findings and other pertinent information are mailed to commercial producers of ornamental plants nine times a year in mimeograph form called the "Massachusetts Nurseryman."

PUBLICATIONS

Bulletins

307 Breeding for Egg Production. By F. A. Hays and Ruby Sanborn. 36 pp. June 1939.

A revised and enlarged edition of a bulletin first published in 1934, presenting results obtained during 25 years of breeding work. It is intended as a guide to assist the poultry breeder in directing his operations.

342 Facts, Fads, and Frauds in Nutrition. By Helen S. Mitchell and Gladys M. Cook. 31 pp. April 1939.

A reprint of a bulletin issued in April 1937, somewhat revised and brought up to date by the inclusion of statements regarding the Food, Drug and Cosmetic Act. Valuable as a guide to the consumer.

355 Annual Report for the Fiscal Year Ending November 30, 1938. 104 pp. February 1939.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

356 Field Corn in Massachusetts. By William G. Colby and Ralph W. Donaldson. 16 pp. February 1939.

This study was undertaken to determine the climatic adaptation of a large number of hybrid and open-pollinated corn varieties and also to review the practices necessary for successful corn culture in this State. A list of varieties tested, with maturity dates and yields over a three-year period, is appended to furnish a basis for determining the suitability of varieties for particular areas.

357 The Effect of Feeding a Vitamin A Supplement to Dairy Cattle. By J. G. Archibald and C. H. Parsons. 14 pp. March 1939.

A vitamin A supplement in concentrated form was added to the grain ration fed to dairy cattle during a period of 22 months to study its effect on the growth and productive function of the animals as well as on milk production. The results, although favorable to the supplement in their trend, were not marked. However, since these cows were on better-than-average rations, it is reasonable to assume that response to the supplement might be greater under average farm conditions, and the slight additional cost of grain mixtures fortified with a vitamin A concentrate seems a cheap insurance against troubles due to deficiency of this vitamin, particularly when the roughage is of poor quality.

358 Blueberry Culture in Massachusetts. By John S. Bailey, Henry J. Franklin, and Joseph L. Kelley. 20 pp. February 1939.

This is a complete revision of a previous bulletin on blueberry culture published in 1935 as Bulletin 317, and contains information on soil requirements, selection of varieties, methods of propagation and culture, pruning, insect and disease control, harvesting, and marketing of cultivated blueberries. Suggestions are given for the improvement of the wild highbush blueberries which occur so abundantly in Massachusetts.

359 Factors Affecting Fertility in Rhode Island Reds. By F. A. Hays and Ruby Sanborn. 15 pp. May 1939.

A report on the behavior of fertility in a breeding program extending over 15 years. Outside temperature during the period when hatching eggs are laid had a specific effect on fertility — fertility increased steadily as outside temperatures rose to about 37° F. Both males and females showed a decline in fertility with increasing age, a decline less marked in females than in males. All the evidence indicates that fertility is controlled by factors other than inheritance and that selective breeding to improve fertility would, therefore, be ineffective.

360 Farm Storages for New England Apples. By C. I. Gunness, W. R. Cole, and O. C. Roberts. 32 pp. March 1939.

Information on design and structure of common and cold storage buildings, refrigeration equipment and operation, management of storage houses, temperature and humidity control, and the physiology and handling of the fruit occupies most of the bulletin. Tests showed that apples which are to be held for a long period should be stored at 32° F. McIntosh apples develop better flavor if the temperature is held at 45° at the time of harvest and reduced to 32° by the third week after picking, but this higher temperature should not be used if the apples are to be held later than January 1.

361 Control of Tomato Leaf Mold in Greenhouses. By E. F. Guba. 36 pp. April 1939.

The successful control of the disease involves cultural practices, greenhouse management, greenhouse location and design, and the use of chemicals for the disinfestation of the greenhouse interior and the protection of the plants from infection. All these factors are discussed and recommendations based on experimental results are made.

362 Haying in the Rain: A Study of Grass Silage. By J. G. Archibald and C. H. Parsons. 19 pp. April 1939.

Unlike corn, grass and legumes require the addition of a preservative at the time the silo is filled in order to make satisfactory silage. At present molasses seems most satisfactory for this purpose from the standpoint of both economy and results, although phosphoric acid may be used. Detailed directions are given for ensiling grass and legumes, using molasses. Feeding trials showed that the molasses–grass silage was about equal to corn silage and somewhat superior to dry hay, although it probably should not entirely replace hay in the ration. It differs only slightly from hay in cost and is generally less expensive than corn silage.

363 Milk Cartage in the Southwick-Agawam Area of the Springfield Milk Shed. By Alfred A. Brown and J. Elizabeth Donley. 26 pp. May 1939.

Analysis of this section of the Springfield milkshed showed that the present type of service under a variety of rates has provided producers with adequate transportation, but the cost has been high, largely because of excessive mileage, light loads, extreme variation in load size, unused truck capacity, and the like. Two plans are suggested for improving the situation: the first is based on reorganization of routes whereby the number of routes was reduced from 12 to 4 and the mileage was reduced more than one third; the other was a reorganization of rate structure by zones.

364 The Significance of Body Weight in Breeding for Egg Production. By F. A. Hays. 16 pp. June 1939.

An analysis of the records of 2,283 Rhode Island Red pullets showed considerable parallelism between monthly body weight and monthly egg weight and egg production. Maximum egg weight occurred about one month earlier than maximum body weight, and the highest level of egg production occurred when body weight was at its maximum in March and April. Figures showed that removal of light-weight pullets on March 1 is an effective means of reducing subsequent mortality. In general, body weight offers a valuable guide to the breeder, particularly from the standpoint of egg size and laying-house mortality.

365 Product-Costs of Milk to Dealers in the Springfield Area, 1935. By Alfred A. Brown and J. Elizabeth Donley. 28 pp. July 1939.

Variations in product-costs (weighted average cost to dealers of milk purchased from producers) in the area are analyzed and suggestions made for reducing them. The milk industry can perform its most effective service under conditions of relative market stability. Among conditions found not conducive to market stability and orderliness are uneven distribution of fluid outlets among dealers, rigidities in producer-distributor relationships, and the absence of reasonable relationships between the price payable for milk disposed of as fluid and as surplus. The disadvantages suffered by all producers, but mostly by producers with inferior sales' outlets, should be minimized by the development and application of a logical pricing technique based on "normal" class price relationships.

366 Towards a Perfect Milk Market. By J. Elizabeth Donley. 28 pp. November 1939.

A normal market should show little duplication of services in procuring its milk and have little surplus at any time of year. This study made in 1935 showed Worcester to be such a market — the producer sells his milk regularly throughout the year, the dealer has very little surplus to dispose of, and the consumer is assured of a regular supply of good milk. The transportation phase seems to be the only part which might be more efficiently organized, but this would involve government control which might prove less desirable than the condition it seeks to remedy.

367 Meteorological Records: A Fifty-Year Summary, 1889-1938. By C. I. Gunness. 23 pp. December 1939.

A summary by months of barometer readings, temperature and humidity, cloudiness and sunshine, precipitation and snowfall, and wind movement for the fifty years that records have been kept at the College. The hurricane of September 21, 1938, was the outstanding storm during this period, and details of the weather on that day are given, with a chart showing the behavior of barometric pressure and wind velocity.

368 Cephalosporium Elm Wilt in Massachusetts. By Malcolm A. McKenzie and Eunice M. Johnson. 24 pp. December 1939.

This disease is rather widespread in Massachusetts and has been the subject of field and laboratory investigations over a period of several years. The macroscopic symptoms are similar to those of the Dutch elm disease, and the fungus which causes the disease is believed to be widely distributed throughout the United States. Affected trees may be progressively weakened and killed, although some trees have apparently recovered and some trees growing in favorable locations seem to be free from symptoms although they do harbor the fungus. Under greenhouse conditions the progress of the disease appeared to be limited in trees infected with a second wilt-inducing fungus, *Verticillium* sp., in addition to *Cephalosporium* sp., since trees infected with both of these fungi did not die back so rapidly as trees infected with either one of the fungi alone.

Control Bulletins

98 Nineteenth Annual Report on Eradication of Pullorum Disease in Massachusetts. By the Poultry Disease Control Laboratory. 12 pp. June 1939.

99 Inspection of Commercial Feedstuffs. By Philip H. Smith. 69 pp. November 1939.

100 Inspection of Commercial Fertilizers. By H. D. Haskins. 50 pp. December 1939.

101 Inspection of Agricultural Lime Products. By H. D. Haskins. 10 pp. December 1939.

102 Seed Inspection. By F. A. McLaughlin. 104 pp. December 1939.

Meteorological Bulletins

601-612, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. By C. I. Gunness. 4 pp. each.

Reports of Investigations in Journals

Numbered Contributions

305 Cranberry juice—properties and manufacture. By C. C. Rice, C. R. Fellers and J. A. Clague. Fruit Produce Jour. 18(7):197-200. 1939.

The juice of the cranberry is well flavored, tart, and attractively colored, and when properly sweetened it makes a very desirable drink. Two methods of expressing the juice are described — heat extraction and cold pressing — and directions are given for making various beverages and syrups. Cranberries and the freshly expressed juice are excellent sources of vitamin C, but some of the vitamin is lost in the manufacturing processes and in storage.

309 Larval development of the native elm bark beetle, *Hylurgopinus rufipes* (Eich.), in Massachusetts. By W. B. Becker. Jour. Econ. Ent. 32 (1): 112-121. 1939.

A study of native elm bark beetles, collected weekly from logs cut from a single American elm and stored in a shaded location, indicates that five stadia occur most commonly, that there was some overlapping in size of successive instars in some cases, and that a difference in size distribution due to sex began to be noticeable in the last two instars.

310 The nutritive value of dried tomato pomace. By W. B. Esselen, Jr., and C. R. Fellers. Poultry Sci. 18(1):45-47. 1939.

This is a waste product from the manufacture of tomato juice and pulp, and consists mainly of skins, seeds, and hard tissue. The data show it to be a good source of vitamin B_1 and a fair source of A and G (B_2). It was readily eaten by chicks from 2 to 6 weeks of age, when fed at the 11.6 percent level. Because of its bitterness, large amounts would probably prove unpalatable to animals.

311 The nutritive value of distillers' by-products. By A. D. D'Ercole, W. B. Esselen, Jr., and C. R. Fellers. Poultry Sci. 18(1):89-95. 1939.

Dried distillers grains or concentrated slop — 10 to 15 percent added to poultry rations — will provide a good and economical source of vitamins B_1 and B_2, which are essential for poultry growth and reproduction.

314 Seasonal variation in chemical composition of common haddock. G. Chapman Crooks and W. S. Ritchie. Food Research 4(2):159-172. 1939.

Water, ash, ether extract, organic nitrogen, ammonia, copper, iron, manganese, and phosphorus were determined in four series of haddock samples caught over a period of one year. The four series included fish frozen whole at sea by means of solid carbon dioxide as soon as caught, fish frozen whole by the Birds Eye method as soon as landed, and commercial fillets frozen by both the Birds Eye and sharp methods. No significant differences were found in the composition of the samples frozen by the various methods, but there was a suggestion of some seasonal variation in certain constituents.

317 Effect of pectin supplements on avitaminosis A in rats. By A. Kobren, C. R. Fellers and Wm. B. Esselen, Jr. Proc. Soc. Expt. Biol. and Med. 41:117-118. 1939.

The pectin appeared to be beneficial in avitaminosis A only insofar as pathological changes in vagina, nares, and eyelids were concerned. It did not delay onset of xerophthalmia, nor did it have any curative action in this condition.

318 Nutritional gizzard lesions in chicks. William B. Esselen, Jr. Poultry Sci. 18 (3):201-209. 1939.

The Massachusetts State College chick ration gave practically complete protection against gizzard lesions. A study of the various ingredients and combinations of them showed that 15 percent each of wheat middlings, wheat bran, and oat groats and 4 percent of alfalfa leaf meal added to the basal lesion-producing ration was almost as effective as the Massachusetts ration. In curative studies alfalfa leaf meal was the most effective of the single materials studied, but the Massachusetts ration which was effective in preventing the lesions was also a very good curative agent. Chicks do not store any great amount of the anti-gizzard-lesion factor in their bodies, but need a constant supply in their feed.

319 The oxidation of ascorbic acid as influenced by intestinal bacteria. By William B. Esselen, Jr., and James E. Fuller. Jour. Bact. 37(5):501-521. 1939.

Certain bacteria, particularly members of the coliform group, inhibited the oxidation of ascorbic acid in culture media. This inhibitory action was stronger with the more actively growing cultures in which the largest number of bacteria were present, and was not observed in the killed cultures. It is suggested that growing bacteria inhibit the oxidation of ascorbic acid by certain combinations of three factors: the formation of un-ionized copper complexes whereby the catalytic action of the copper is destroyed; the production of carbon dioxide with the subsequent saturation of the medium with it; and the lowering of the oxygen tension of the medium. The most effective inhibitory action was obtained with a combination of all three of the factors.

320 Effect of particle size on the solubility of magnesium in dolomite and magnesic limestone in 4 percent citric acid solution adjusted to pH 4.0 with ammonium hydroxide. By J. W. Kuzmeski. Jour. Off. Agr. Chem. 22 (1):147-150. 1939.

The results seem to justify the belief that the solubilities recorded might have a definite ratio to the rate of solubility or availability of the magnesium and calcium in a limestone product in the soil. They also emphasize the great advantage of fine grinding from the standpoint of immediate effectiveness of the product, both in neutralizing value and in furnishing available plant food.

321 The effect of apples and cranberries on calcium retention. By Abraham Mindell, William B. Esselen, Jr., and Carl R. Fellers. Amer. Jour. Digest. Diseases 6(2):116-119. 1939.

Body calcium retention of white rats was increased 8.4 percent when fresh cranberries made up to 20 percent of an adequate diet, and 10.8 percent when apples were fed at the same rate. Cranberries seemed to increase the calcium content of the femur ash slightly, but apples showed no significant effect.

322 Dextrose in the food industries and its health status. By Carl R. Fellers. Amer. Jour. Pub. Health 29(2):135-138. 1939.

Dextrose can be advantageously used to replace from 15 to 50 percent of the sucrose in the manufacture of fruit preserves, jams, fruit syrups, sweet pickles, and certain canned foods such as apple sauce, peaches, pears, peas, and citrus juices. Dextrose is somewhat superior to sucrose in preservative action, especially at higher concentrations, and because of its lower sweetening power, it does not mask the fruit flavor so much as equivalent quantities of sucrose.

325 Factors to be considered in selecting chocolate-flavored milk. By W. S. Mueller. Jour. Dairy Sci. 22(8):623-636. 1939.

Ordinary amounts of cocoa (1 percent) do not decrease the nutritive value of milk, but 4 percent definitely decreases the digestibility of the milk. The bacteria count of some of the commercial chocolate-flavored syrups was high enough to cause considerable contamination when they were added to cold milk, although no pathogenic organisms were found in any of the syrups or cocoas.

326 Influence of bacteria on oxidation of ascorbic acid. By William B. Esselen, Jr. Food Research 4(4):329-334. 1939.

Most of the 45 strains of bacteria studied significantly retarded the oxidation of ascorbic acid, especially when they were grown in a medium containing a readily fermentable carbohydrate. There was no evidence that bacteria are destructive to ascorbic acid. It would appear, therefore, that bacteria are not of importance in causing a loss of ascorbic acid in foods.

327 Canned baked apples. By John Ruffley, Jr., John A. Clague, and Carl R. Fellers. Canning Age 20(2):68-70, 82 and (4):179-181. 1939.

Baked apples make a satisfactory canned product, but glazed apples are more attractive and finer flavored and take less time. For either baking or glazing a syrup of not more than 40° Brix is recommended, and the use of 5 percent honey or 20 percent dextrose with the sucrose gives good results. For hot-filled No. 2 cans, processing for 12 minutes at 212° F. insures sterilization. Varieties of moderately high acid and pectin, such as Baldwin, York, Rhode Island Greening, Gravenstein, and Northern Spy, are good for baking and canning.

328 Dealing with storm damage in central Massachusetts. By Malcolm A. McKenzie. Eastern Shade Tree Conf. Proc. 1938:29-34. 1939.

A discussion of the damage to shade trees by the hurricane of September 21, 1938, telling what has been done to restore and replace trees which were damaged or destroyed and warning of the danger of disease and insect injury which is likely to follow the hurricane damage.

329 Present status of pullorum disease in the United States. By Henry Van Roekel. Proc. Seventh World's Poultry Congress and Exposition, Cleveland, Ohio, 1939.

Testing data from various states are presented to show that pullorum disease-free flocks can be established and maintained and that pullorum disease control and eradication are progressing rapidly in many states.

330 A quantitative study of form and size in five varieties of carrots. By W. H. Lachman. Amer. Soc. Hort. Sci. Proc. 36(1938):623-625. 1939.

While there is some variability in both shape and size of carrots, it is apparent that shape is decidedly the more constant of the two characters and is less influenced by soil variability. When studied on a statistical basis, shape indices may be manipulated with confidence and small though clear-cut differences may be ascertained.

331 New and easy ways to prevent damping-off of seedlings. By W. L. Doran. Amer. Florist 1(2):2. 1939.

Ordinary vinegar is a good disinfectant for preventing damping-off of seedlings when applied to soil at the rate of 1 pint per square foot before the seed are sown. After sowing small seeds, it is a good practice to water the soil from below by setting the containers into shallow pans of water and removing them as soon as the soil becomes saturated; and if preferred, a soil fungicide may be applied at this time. Satisfactory control of damping-off without injury to the seeds has been obtained by 1½ quarts of vinegar or 2 to 3 teaspoonfuls of formaldehyde to a gallon of water, applied in this way.

332 Relation of seeds to pre-harvest McIntosh drop. By Lawrence Southwick. Amer. Soc. Hort. Sci. Proc. 36(1938):410-412. 1939.

A moderate but statistically significant correlation was found between seed number and time of pre-harvest drop of the McIntosh apple. Seed number varied widely for different trees, probably as a result of variability in the effectiveness of pollination, but this did not seem to alter appreciably its association with the date of drop.

333 Further notes on the Malling clonal stocks in relation to McIntosh and Wealthy. By Lawrence Southwick and J. K. Shaw. Amer. Soc. Hort. Sci. Proc. 36(1938):113-137. 1939.

Variability studies indicate that very little benefit can be expected from the use of clonal-rooted trees in establishing and maintaining performance uniformity in an orchard in Massachusetts.

334 Abnormal behavior of newly set Oldenburg buds. By J. K. Shaw. Amer. Soc. Hort. Sci. Proc. 36(1938):126-128. 1939.

Of 150 buds set in August 1937, only about 30 percent grew normally. The others produced all sorts of abnormal flowerlike growths and various intergrades between flowers and shoots. Most of the abnormal growths later developed leafy shoots that grew into good one-year whips but were not so tall as those that started normally.

336 The effect of storage methods on ripening and quality of tomatoes. By Eleanor A. West and Grant B. Snyder. Amer. Soc. Hort. Sci. Proc. 36 (1938):695-700. 1939.

The optimum length of storage, at temperatures of 45° to 50° F. and relative humidity of 45 percent, was between 20 and 30 days for firm ripe tomatoes and 30 days or more for green mature tomatoes. The latter developed a red color during storage. Shrinkage, including loss of weight and losses from disease, was least for green tomatoes. In the comparison of different methods of storage, shrinkage was least for fruit washed with formaldehyde and then protected against subsequent contamination.

337 Cereal flours as antioxidants in dairy products. By W. S. Mueller and M. J. Mack. Food Research 4(4):401-405. 1939.

Finely milled oat flour, whole oat flour, and corn flour had similar antioxidative properties when used in milk; but wheat, both whole and bleached, barley, rye, and rice flours had but little antioxidative value. Corn flour had antioxidative properties equal to those of oat flour when used in ice cream, and was somewhat more effective as a stabilizer.

338 Report on Zinc. By E. B. Holland and W. S. Ritchie. Jour. Assoc. Off. Agr. Chem. 22(2):333-338. 1939.

Work on the colorimetric method for the determination of zinc in foodstuffs was continued, with a modification of many details of the process and its expansion to permit the determination of both copper and lead when desired. The method, which is presented in detail, has given results sufficiently promising to warrant cooperative work on the part of the Association.

339 Vitamin C content of spinach. By C. F. Dunker and C. R. Fellers. Amer. Soc. Hort. Sci. Proc. 36(1938):500-504. 1939.

Fresh raw spinach contains from 400 to 450 international units of vitamin C per ounce. One third to two thirds of the ascorbic acid is lost in cooking, depending on the amount of "cook water" used; in general the larger the amount of water the greater the loss. The canning of spinach causes loss of 60 to 65 percent of its vitamin C; freezing and incidental operations cause losses approximating 45 percent; dehydration results in total loss.

344 Equine encephalomyelitis virus (eastern type) isolated from ring-necked pheasant. By H. Van Roekel and Miriam K. Clarke. Amer. Vet. Med. Assoc. 94 (n. s. 47):466-468. 1939.

Equine encephalomyelitis virus (eastern type) was identified in pheasants submitted to this laboratory by the New Jersey Station. The English sparrow was shown by experimental inoculation to be susceptible to this virus and should be added to the list of hosts which may contract the disease.

346 Potatoes as carriers of vitamin C. By Mary E. Lyons and Carl R. Fellers. Amer. Potato Jour. 16(7):169-179. 1939.

Potatoes are a much cheaper source of vitamin C than either orange or tomato juice, and an ordinary serving will supply about one third of the daily requirement. The ascorbic acid content of potatoes was not significantly affected by geographical source, time of harvest, or size; but about half the original content was lost during ordinary home storage from December to May. About 40 percent of the ascorbic acid was lost in baking or boiling.

347 Effect of several calcium salts on the utilization of lactose. By Helen S. Mitchell, Gladys M. Cook, and Katherine L. O'Brien. Jour. Nutrition 18(4):319-327. 1939.

The addition of calcium salts to an adequate ration containing 60 percent lactose had little effect on the digestion of the lactose by rats, except in the case of calcium gluconate, which seemed to prevent most of the lactose from leaving the intestinal tract. The effect of sodium gluconate was even more pronounced. It would seem, therefore, that the gluconate radical in some way inhibits lactase activity.

348 Absence of linkage between genes for early sexual maturity and genes for high persistency in egg production in the domestic fowl. By F. A. Hays. Proc. Seventh World's Poultry Congress and Exposition, Cleveland, Ohio. 1939.

A study of 911 Rhode Island Red females showed that the apparent correlation between age at sexual maturity and length of biological laying year was spurious. The data further indicated independent inheritance of genes for early sexual maturity and genes for high persistency. No evidence appeared, however, against the expediency of selecting breeding stock on the basis of length of biological laying year.

355 Infectious avian encephalomyelitis. By H. Van Roekel, K. L. Bullis, and M. K. Clarke. Jour. Amer. Vet. Med. Assoc. 34:754-755. 1939.

This disease has made its appearance in many states, with the greatest incidence apparently in the northeastern states. Several of the breeds, both light and heavy, have been found susceptible. Under commercial practices the disease is transmissible among chicks through direct contact. The infective agent appears to be transmitted through the egg from the hen to its progeny. No reliable method of control has yet been worked out.

Unnumbered Contributions

Twelve dependable shrubs. By William L. Doran. Flower Grower 26(4):187, 200-201. 1939.

Seed and seedling troubles. By C. J. Gilbut. Horticulture 17(6):144-145. 1939.

Control calendar foı vegetable pests. By E. F. Guba and W D. Whitcomb. Mass. Ext. Serv. Leaflet 116 (Revised). May 1939.

Fungi of Nantucket II. By E. F. Guba. Rhodora 41:508-520. 1939.

Dealing with storm damage in central Massachusetts. (Excerpts from Contribution 328.) By M. A. McKenzie. Jour. N. Y. Bot. Garden 40(470):43-45. 1939.

Twenty years in two hours. By M. A. McKenzie. Proc. of the 28th Ann. Meeting of the Mass. Tree Wardens' and Foresters' Assoc. p. 20-22. 1939.

Some factors to be considered in selecting chocolate-flavored milk. By W. S. Mueller. Contact vol. 2, no. 4, June 1939.

Status of pasteurization of milk and milk products. By M. J. Mack et al. Amer. Jour. Pub. Health Yearbook. Supplement to vol. 29, no. 2, 1939.

The year's research record. By M. J. Mack. Ice Cream Trade Jour., April, 1939.

Egg solids in ice cream. By M. A. Widland and M. J. Mack. Ice Cream Trade Jour., October 1939.

Milk is effective in a reducing diet. By J. H. Frandsen. Milk Plant Monthly, July 1939.

Factors affecting the vitamin C content of milk. By Myer Glickstein and J. H. Frandsen. The Milk Dealer, August 1939.

New insect problems of Massachusetts fruit growers. By W. D. Whitcomb. Mass. Fruit Growers' Assoc. Ann. Rpt. 1939:156-164.

Survey of fruit insect pests in Massachusetts in 1938. By W. D. Whitcomb and A. I. Bourne. Mass. Fruit Growers' Assoc. Ann. Rpt. 1939:28-32.

The comparative value of honey bees in the pollination of cultivated blueberries. By F. R. Shaw, J. S. Bailey, and A. I. Bourne. Jour. Econ. Ent. 32 (6):872-874. 1939.

The nutritional and practical aspects of quick frozen foods. By Wm. B. Esselen, Jr. Jour. Amer. Diet. Assoc. 15:377-379. 1939.

The vitamin B_1 and vitamin B_2 (G) content of vegetables—Influence of quick freezing and canning on vitamins B_1 and B_2 (G). By C. R. Fellers, W. B. Esselen, Jr., and G. A. Fitzgerald. Quick Frozen Foods 1(8):24-25. 1939.

Experiments with dextrose in pickles and kraut. By C. R. Fellers. Fruit Prod. Jour. vol. 18, no. 8. April 1939.

Health values of pickles and kraut. By C. R. Fellers. Fruit Jour. 18:276. 1939.

What factors help destroy vitamins in cooking foods? By A. S. Levine. Food Field Reporter 7(10):31, 32. 1939.

Nutrition vs. heredity in determining stature. A review. By A. S. Levine. Growth 3:53-59. 1939.

Food—friend or enemy, or Tell me what you eat and I'll tell you what you are. By C. R. Fellers. The Internatl. Steward 36:15, 18-19. 1939. Hotel and Restaurant News 14(19):2. Sept. 2, 1939.

Canning Atlantic crab meat. (Abstract.) By C. R. Fellers and S. G. Harris. Fishing Gazette 56(9):17. 1939.

A clean service for every customer every time. By R. H. Barrett, C. R. Fellers, and J. Novick. A report of a study of costs. 24 pp. Sept. 1939.

Development of our native crab fisheries stressed as a way to combat "Jap" imports. By C. R. Fellers and S. G. Harris. The Internatl. Steward 36(2):7. 1939.

What's new in foods? By C. R. Fellers. Internatl. Steward 35 (7):16-17; (8):16-17; (9):20-22. 1939.

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Superlative plants for the perennial border. By Ray M. Koon. Real Gardening 2(5):39, 51-55. 1939.

A new aster, the Curtis Pink. By Ray M. Koon. Horticulture 17(22):481. 1939.

Compost pile counsel. By Paul W. Dempsey. Real Gardening 1(12):39, 16-18. 1939.

Making them grow; organic matter in the home garden. By Paul W. Dempsey. Real Gardening 2(5):39, 60-65. 1939.

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Transmissible Fowl Leukosis A Review of the Literature

By Carl Olson, Jr.

There is much confusion regarding our knowledge of "fowl leukoses," which can be largely overcome through analysis and organization of all available information on the subject. This is an attempt to attain that objective.

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TRANSMISSIBLE FOWL LEUKOSIS. A REVIEW OF THE LITERATURE[1]

By Carl Olson, Jr.
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INTRODUCTION

A group of diseases sometimes referred to as "fowl leukoses" has become of much interest in the past few years to those concerned with diseases of the domestic chicken. These diseases represent a serious menace to the poultry industry because of the large losses which are caused by them. The actual loss that may be attributed to this group of diseases is very difficult if not impossible to evaluate with any degree of precision. It may be said, however, that the losses due to these diseases are greater than those from any other disease for which we as yet have no adequate means of control.

There is considerable uncertainty as to the relationship between the various disease processes which have been described in the literature under the term "fowl leukoses." This uncertainty is due in part to the varying results that have been obtained in the experiments of different investigators and also to indiscriminate use of terms applied to the disease processes. Such a state of confusion is not conducive to clear understanding of the fundamentals of these diseases. It would seem, therefore, that a review of the literature on transmissible fowl leukosis would be of considerable value to those who are interested in the problem but who have neither the time nor the facilities to engage in an exhaustive study of the literature. It is with this purpose in mind that this discussion is presented.

Although the disease process referred to as "transmissible fowl leukosis" constitutes the main subject of this review, it is necessary to elaborate upon the other diseases sometimes classified with it in the group of so-called "fowl leukoses." It is preferable to use the term leukosis or transmissible fowl leukosis in the restrictive sense to indicate a single entity in which there is a characteristic disturbance of the myeloid tissue. The term will be used in this sense throughout this review except where quotation marks indicate the use of the term in the sense implied by the particular author cited.

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[1] This article is a revision of a portion of a thesis submitted to the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Doctor of Philosophy, while associated with the Mayo Foundation, Rochester, Minn.

HISTORICAL ASPECTS

The disease of fowl leukosis was first described in 1896 by Caparini (23) in Italy. It is of interest that leukemia in man was described in 1845 (Craigie 25, Bennett 12, and Virchow 208) and had also been previously described in other lower animals: horse in 1858 (127), swine in 1865 (127), cat in 1871 (180), dog in 1874 (17, 18), and bovine species in 1876 (180). Warthin (215), Koch and Rabinowitsch (122), and Kon (123) made observations on the spontaneous occurrence of fowl leukosis in 1907. Butterfield (22) in 1905 described three livers of hens on which he made the diagnosis of "aleukemic lymphadenosis." These probably were not examples of the disease now recognized as transmissible fowl leukosis, as there was no indication of a leukemic state. However, in this report, Butterfield mentions a communication from Dr. J. R. Mohler of the Bureau of Animal Industry, United States Department of Agriculture, describing five cases in each of which there was evidence of a leukemic state in conjunction with infiltration of the visceral organs. These cases might possibly represent instances of fowl leukosis.

A significant advance was made by Ellermann and Bang (45) who in 1908 reported the successful transmission of the disease with a filtrable agent. Hirschfeld (93) and Hirschfeld and Jacoby (94), working with leukosis agent derived from the original strain of Ellermann and Bang, confirmed the findings as to transmission and ruled out tuberculosis as the cause of the disease, an idea advanced by Burckhardt (19). In 1915 Schmeisser (177) reported the development of another transmissible strain of fowl leukosis and in the same year Magnusson (133) reported transmission of the disease. Since this time a number of different transmissible strains of the disease have been described by investigators in various parts of the world, as indicated in the appended synopsis.

The occurrence of the disease has been reported in Denmark (45), Germany (130), England (11), Sweden (133), Italy (6), Hungary (97), Russia (218), Holland (197), Japan (139), United States (215), France (151), South Africa (95), Brazil (168), and New Zealand (65).

TYPES OF TRANSMISSIBLE FOWL LEUKOSIS

Ellermann (38, 39, 43, 44) distinguished three general types of leukosis; namely, myeloid leukosis (leukemic and aleukemic), intravascular lymphoid leukosis (also known as erythroleukosis) and lymphatic leukosis (an extravascular process). Later investigators have, in general, followed the classification which he propounded, although certain exceptions to the relationship between these various forms have been made.

Erythroblastic Leukosis

Synonyms for this form of leukosis are: erythroleukosis (Ellermann 44, Furth 72), intravasculare lymphoid leukose (Ellermann 39), leucose á cellules sanguines primitives (Andersen and Bang 2), erythroblastosis (Engelbreth-Holm and Rothe Meyer 55), mielosi eritremica (Battaglia and Leinati 6) leukomyelose (Kitt 121), leucémie érythroblastique (Oberling and Guérin 146), erythromyelosis (Bayon 7), and mielosi eritremica normoblastica transmissible (Storti and De Filippi 184).

Two types of erythroblastic leukosis are recognized by many investigators among whom are Jármai (99), Furth (72), Stubbs and Furth (194), Bedson and Knight (11), Engelbreth-Holm and Rothe Meyer (55), and Oberling and Guérin

(146). The more commonly observed form of erythroblastic leukosis is evidenced by the presence in the blood of many immature erythroblastic cells and by certain characteristic alterations of the tissues which have been discussed in a previous report (155). The other form, anemic erythroleukosis, is recognized as a subvariety in which there are relatively few immature cells in the circulating blood. The predominating feature is a marked anemia with only minor changes in the tissues other than the bone marrow. Intermediary and transitional forms of erythroblastic leukosis (between the anemic and well-developed forms) have also been observed (155).

Granuloblastic Leukosis

Synonyms for this form of leukosis are: myeloid or myeloic leukosis (Ellermann 42), myelosis myeloidea (Battaglia and Leinati 6), leukomyelosis (Kitt 121), leucocythemia (Bayon 8), and leukemic myeloblastosis (Nyfeldt 142).

Ellermann (38) described leukemic and aleukemic types of myeloid leukosis. The leukemic forms were further subdivided into a myeloblastic and a myelocytic form, but no sharply defined distinctions between the two were observed. The disease described by Ellermann as "aleukemic myelosis" has been regarded by Mathews (137), Feldman (62), and Feldman and Olson (63) as a definite neoplastic process composed of myelocytes and designated as myelocytoma. Ellermann's "leukemic myelosis" has been recognized as being associated with and caused by the exciting agent of fowl leukosis. It is differentiated from erythroblastic leukosis by the fact that the predominating immature cells in the circulating blood are of the granulocytic series. There are instances recognized in which the blood reveals many immature cells of both erythrocytic and granulocytic lines of development. In these last named cases the term "mixed leukosis" is sometimes applied (Furth 71).

TYPES OF DISEASE SOMETIMES CLASSIFIED AS "FOWL LEUKOSES"

Lymphocytoma

Synonyms for this disease are: lymphatische leukose (Ellermann 43), myelosis haemocytoblastica (Battaglia and Leinati 6), aleukemic lymphadenoma (Butterfield 22), lymphadenoma (Mathews and Walkey 138), lymphomyelose (Kitt 121), lymphomatosis, visceral-lymphomatosis and hemocytoblastosis (Johnson 107, 108), leucose á leucoblastes (Andersen and Bang 2), lymphosarcoma, and lymphocytomatosis.

Lymphatic leukosis was the third general type of leukosis considered by Ellermann (43) to be caused by the filtrable agent of transmissible fowl leukosis. It is noteworthy, in the light of more recent work, that many of the cases described by Ellermann were of spontaneous occurrence in chickens that had not been inoculated.

This form of disease is described and given the name lymphocytoma by Feldman (62). Lymphocytoma may be regarded as a malignant neoplastic disease, the undifferentiated lymphocyte being the type cell of the tumor. Andersen and Bang (2) give an excellent description of the disease and suggest that the type cell is the leukoblast. This designation would imply the potentiality of the type cell to develop into either the granulocytic or monocytic series of blood cells as well as the lymphatic series. As no such differentiation of the tumor cell takes place it is better to regard the type cell as either a dedifferentiated or undifferentiated lymphocyte. The liver is often the site of many large foci of the neoplastic cells, although in many cases the distribution of the cells in the tissues is diffuse. The intestines and mesentery, kidneys, ovary, lungs, heart, adrenals, subcutaneous tissues, and the spleen are locations in which the neoplastic process may occur. The tumor cells are always situated extravascularly. Changes in the peripheral blood are somewhat difficult to observe, as usually a chicken affected with this disease dies suddenly without visible evidence of disease. Nevertheless, Fenstermacher (64) was able to make monthly observations of the blood of 79 chickens found at the time of death to be affected with lymphocytoma and noted no characteristic change in the blood. Ellermann (43) and Andersen and Bang (2) state that there are no changes of the blood in this disease. Schaaf (175) reported that he observed a few instances of spontaneous leukemic lymphocytoma in which the diagnosis was based on histological study only.

Lymphocytoma is not uncommon, and might prove to be the most common type of neoplastic disease of the domesticated chicken if we but had the proper data from which reliable information could be gained. Fenstermacher (64) observed an incidence of 15.9 percent cases of lymphocytoma among 494 chickens raised beyond six months of age. It is worthy of note that he found the incidence of disease decreased in the second and third generations of birds derived from this stock.

There are tumors, occurring rather frequently in the fowl, in which the morphology of the cells constituting the mass or masses is such that identification of the type cell is difficult. Jackson (95) discusses this group and gives them the name "mixed cell sarcoma" although he states that this term should not be used without an understanding of the predominating cell which constitutes the tumor in question. The feasibility of using a qualifying term as "histiocytic" or "fibroblastic" as suggested by him is a point to be considered. There can be no doubt that neoplastic disease of this type (especially "histiocytic sarcoma") has been diagnosed without qualification or distinction as lymphomatosis. Round-celled sarcoma, lymphosarcoma, and mixed cell sarcoma are terms which have been used to indicate this or similar types of neoplastic disease in the chicken (Joest and Ernesti 106, Pentimalli 164, Eber and Kriegbaum 33, Eber and Malke 34, Følger 66, and others). The characteristics of these neoplasms as well as their probable derivation from a cell similar to that which gives origin to the cells of a lymphocytoma are reasons for the tentative linking together of these diseases. The name "atypical lymphocytoma" has been used in referring to this type of reaction (such a case is described in a report by Olson and Dukes, 157), which, although a somewhat ambiguous term, expresses a certain relationship to the more clearly defined disease of lymphocytoma.

A condition of "lymphoblastoma" has been described by Adamstone (1) as occurring in young chicks fed a diet treated with ferric chloride to destroy vitamin E. The condition described by him is dissimilar to lymphocytoma or atypical lymphocytoma and its exact nature is difficult to determine, although Jungherr (116) has suggested that it may be of an inflammatory character.

Jungherr (114) and Jungherr and Landauer (117) described a condition of osteopetrosis which they found transmissible and sometimes associated with lymphocytoma-like reactions. Other workers have encountered this condition so infrequently that no further mention of it will be made in this discussion.

Failures to transmit lymphocytoma by experimental inoculation have been reported by Andersen and Bang (2), Mathews and Walkey (138), Engelbreth-Holm (47, 48, 50), and Fenstermacher (64). Some workers claim to have transmitted this disease successfully and believe that there is a common etiologic agent for lymphocytoma, fowl paralysis, and transmissible leukosis (Patterson, Wilcke, Murray and Henderson 163, Johnson 108, and Lee, Wilcke, Murray, and Henderson 125, 126). Others (Pappenheimer, Dunn, and Seidlin 162, Seagar 179, Jungherr 115, and Gibbs 87) present data of transmission experiments to suggest the association of lymphocytoma and fowl paralysis.

Furth (77, 78, 80) has developed an agent (known as Strain 2 agent) which originated in a chicken inoculated with his Strain 1 (Strain 1 produced only erythroblastic or myeloblastic fowl leukosis) and which upon inoculation into susceptible birds gives rise to what he terms lymphomatosis and occasionally myelomatosis and endothelioma. This neoplastic disease was characterized by local lymphomatous tumor formation at the site of inoculation, after intramuscular inoculation with viable cells. This was accompanied by extensive lymphomatous infiltration of the liver, spleen, and bone marrow, and less frequently of the thymus, kidneys, heart, muscle, lungs, ovary, nerves, and nerve ganglia. Following inoculation with material devoid of living cells, no local tumor formation developed but changes were noted in the visceral organs and bone marrow of the animals (only eight instances of such a reaction occurred among 39 chickens so inoculated). The reaction of lymphomatosis was usually associated with anemia and an increase of large lymphocytes in the circulating blood. In the case of myelomatosis there was an increase of myelocytes in the blood. The reaction noted in the blood was in some instances very similar to and difficult to differentiate from erythroblastic leukosis. Furth, however, interpreted the process as a condition associated with the primary disturbance of the lymphoid tissue. When the Strain 2 agent was inoculated into a nerve a localized thickening and infiltration of adjacent tissues resulted, but this local reaction and the cellular reactions noted in the nerves of chickens inoculated by other routes were not believed by Furth to represent the condition of fowl paralysis. Furth (81) observed a transmissible osteochondrosarcoma in a chicken that had received an intravenous inoculation of blood from a bird previously inoculated with the Strain 2 agent. In the course of transmission experiments with this tumor it was found that implantation of the tumor produced either the tumor, or lymphomatosis, or a combination of both; but that successive passages made by intravenous or intramuscular inoculations of blood from birds with lymphomatosis gave rise to lymphomatosis only. He, therefore, believed that the osteochondrosarcoma was caused by an agent (Strain 12) which had come into association with the Strain 2 agent. It is of interest that Furth (80) distinguished this transmissible disease caused by the Strain 2 agent from "spontaneous lymphomatosis" associated with marked enlargement of the liver ("big liver disease," "hepatolymphomatosis"). He believes that there is no state of leukemia or involvement of the peripheral blood in the latter disease. The transmissible lymphomatosis of Furth was regarded by him as being a rare spontaneous disease of chickens. It is difficult to place in any particular class and its inclusion in this section on lymphocytoma is entirely arbitrary.

Olson and Zeissig (159) studied the antigenic properties of normal tissues of the chicken (thymus, bursa of Fabricius, and peripheral nerve) and tissues containing pathological infiltrations of lymphoid cells (lymphocytoma and nerves in instances of fowl paralysis). No antigenic differences between normal and pathological lymphoid tissue could be detected in the antiserums prepared by injection of rabbits with the respective materials.

The basal metabolic rate of chickens affected with lymphocytoma, atypical lymphocytoma, or myelocytoma was found by Olson and Dukes (157) to be markedly increased, whereas it was observed to be normal in chickens with fowl paralysis and only moderately elevated in birds affected with leukosis produced by the Strain 2 agent of Furth.

Myelocytoma

Synonyms: leukochloroma (Mathews 137), aleukemic myelosis (Ellermann 38), aleukemic myeloblastosis (Nyfeldt 142), and myeloma.

This disease in the chicken was first described by Ellermann (38), who termed the condition "aleukemic myelosis" and believed it to be caused by the filtrable agent of transmissible fowl leukosis. Mathews (137) described the disease and gave it the name "leukochloroma," deriving this term from human pathology.

Myelocytoma is a neoplastic disease of the fowl in which the myelocyte is the type cell. The tumor has a characteristic appearance. It is devoid of pigment, has a chalky white color, and is very soft. The neoplastic masses are usually found associated with the periosteum of the sternum, ribs, and vertebrae and somewhat concentrated at the junction of the costal and sternal ribs. Soft structures in which foci of myelocytoma have been described are the liver, spleen, ovary, kidneys, heart, intestine, pancreas, thymus, and occasionally the lungs, sciatic nerves, esophagus, trachea, and thyroid gland. The cells of a myelocytoma may be readily studied in imprint preparations.[2] Polychrome myelocytes as well as myelocytes may be found in imprint preparations of a myelocytoma. The myelocytes have granules which are round and acidophilic. The polychrome myelocytes possess both acidophilic granules and basic staining preacidophilic granules in their cytoplasm. The nuclei of these cells are usually round or slightly indented and have a finer chromatin and parachromatin arrangement than is found in either the mature heterophil or eosinophil of the blood. Although Jackson (95) calls attention to the fact that these cells may be morphologically identical with the myelocytes of the bone marrow, which normally develop into the blood heterophil with spindle-shaped granules in the cytoplasm, their identity cannot yet be considered settled as knowledge of the relationships between the various blood cells in the tissues of the chicken is not yet complete. It is conceivable that these cells might be derived from the tissue histiocyte.

In some instances, this disease is accompanied by an increase of heterophils and circulating myelocytes in the blood. These circulating myelocytes are indistinguishable from those found in the neoplastic deposits. It would be possible to arrange a series of cases presenting the varying gradations from an instance of myelocytoma in which the blood is normal to the frankly leukemic condition of granuloblastic leukosis.

Mathews (137) attempted transmission of the disease to 23 experimental chickens. His material for inoculation was derived from three spontaneous cases of the disease and was introduced intraperitoneally, subcutaneously, subperiosteally, and orally. In no instance did the disease occur in the inoculated animals. Furth (77) observed instances of the disease in fowls inoculated with his Strain 2 agent.

Fowl Paralysis

Synonyms of this condition are: polyneuritis (Marek 136), neuritis (Doyle 30), fowl paralysis (Warrack and Dalling 214), range paralysis or "leukosis" (Patterson and others 163), lymphomatosis (Johnson 107), Mareksche Geflügellähmung, neuromyelitis, paralysis, and neurolymphomatosis gallinarum (Pappenheimer et al. 160).

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[2] These are made immediately after death of an affected bird by lightly touching a bit of the tumor tissue against the surface of a clean slide. The imprint is dried in the air and then stained with the usual blood stains, more or less concentrated according to the density of the imprint.

The essential features of the pathological anatomy of this disease have been well described by numerous workers (Kaupp 119, Pappenheimer, Dunn, and Cone 160 and 161, Patterson, Wilcke, Murray, and Henderson 163, Warrack and Dalling 214) and will be considered only briefly. The symptoms consist of an asymmetrical, partial, and progressive paralysis of the legs or wings and less often of the neck muscles. There are occasional cases in which a gray discoloration of the iris may be noted. The duration of the disease is variable and some individuals may recover although death is the usual result. The principal pathological changes are to be found in the dorsal root ganglia of the spinal segments and the peripheral nerves. These changes are an infiltration of polyblasts (lymphocytes, histiocytes, and plasma cells) in the nerve trunk with myelin degeneration and increase of the Schwann sheath cells. Sometimes the infiltrating cells assume an almost neoplastic aspect and undergo marked proliferation. Perivascular accumulations of mononuclear cells may occur in the central nervous system. The changes in the eye associated with the disease consist of an iridio-cyclitis in which polyblasts are the infiltrating cells (Jaensch and Lerche 96). Visceral lymphocytomas, usually of the ovary, are found in a variable percentage of the cases. No marked alterations of the peripheral blood are associated with the disease (Johnson and Conner 111, Jungherr 113, Beach and Twisselmann 10).

Potel (165 a) studied 32 hens affected with fowl paralysis, 11 of which had neoplastic-like lesions in the visceral organs. He came to the conclusion that the disease was neoplastic rather than inflammatory in character and that fowl paralysis and fowl leukosis were but different manifestations resulting from the action of a common causative agent. Fritzsche (68 a) states that this conception of Potel's is untenable even on the basis of a study of the pathological cells alone without considering the epizoology and results of experimental transmission. The latter two factors cause the distinction between the two diseases to be still more evident.

Both successful and unsuccessful attempts at experimental transmission of fowl paralysis have been reported. Some investigators believe that fowl paralysis, lymphocytoma, and transmissible fowl leukosis are caused by a single disease-producing agent. Others have come to the conclusion that one agent may cause fowl paralysis and lymphocytoma. These relationships have been mentioned in the section dealing with lymphocytoma. The investigators who have reported the successful transmission of fowl paralysis by means of experimental inoculation are Pappenheimer, Dunn, and Cone (160), Pappenheimer, Dunn, and Seidlin (162), Patterson, Wilcke, Murray, and Henderson (163), Seagar (179), Jungherr (115), Johnson (108), Lerche and Fritzsche (128), Furth (79, 80). Other early contributions dealing with the role of parasites in the etiology of fowl paralysis have been reviewed by Biely and Palmer (14). Unsuccessful attempts at experimental transmission of the disease were reported by Kaupp (119), Doyle (30), Jungherr (113), Dalling and Warrack (28), Barber (4), Beach (9), and Olson (156). Some investigators have advanced the idea that the disease may be transferred from the parent to the offspring. Gibbs (88) described what he considered to be the pathological type cell in the semen of male chickens and suggested that these cells might infect the eggs fertilized with such semen. He also described the pathological type cell in the follicular fluid of the ovules. While this is an entertaining conception, there are almost insurmountable difficulties attendant upon the identification of a cell which may be said to be specific for fowl paralysis if in fact such an entity exists. Asmundson and Biely (3) and Biely, Palmer and Asmundson (15) presented data which tend to demonstrate an inherent difference in susceptibility or resistance to fowl paralysis and lymphomatous tumors between groups of chickens of different breeding. The experience of Dalling and Warrack (28) was that certain individual females would produce progeny among which there was a relatively high incidence of fowl paralysis and lymphoid tumors irrespective of whether they themselves were affected with the disease and regardless of the sire used. Madsen (131), using as parent stock hens affected with the iritis associated with fowl paralysis, raised two generations of chickens and obtained results which seemed to indicate that the incidence of diseases of these types was less in the progeny. Durant and McDougle (32) have recently reported the experimental production of fowl paralysis by the inoculation with blood from chicks whose parents were affected with the iritis form of the disease. The blood of these chicks appeared to be more capable of inducing the disease at certain times than at others, age apparently being the controlling factor. Only eight of the 22 chicks furnishing blood for the inoculations showed evidence of the disease up to ten months of age. A total of 527 chicks was inoculated and 507 were held as controls with the result that fowl paralysis (both lesions of the peripheral nerves and iritis) was observed in 17.1 percent of the experimental group and 3.55 percent of the control group. The incidence of tumors and leukosis was found to be low and approximately the same in both groups.

The possibility that normal birds develop the disease as a result of contact or cohabitation with affected chickens has been considered for many years (Doyle 31, Gildow, Williams, and Lampman 89) and this question still awaits definite conclusion.

It is noteworthy that none of the investigators have been able to enhance the virulence of the causative agents developed by them to the extent that there is an overwhelming majority of successfully inoculated birds as compared to the incidence of spontaneous disease among those used for the purpose of control of the experiment. The lack of good evidence on the mode of spontaneous development after natural exposure to the disease is a serious handicap. Most of those who have worked with the disease express the opinion that it is infectious in nature. However, the actual demonstration of its infectious character by experimental transmission is not yet on a very firm basis.

INCIDENCE OF FOWL LEUKOSIS

There are few data available to furnish accurate statistics as to the frequency of occurrence of fowl leukosis, largely because of the different systems of nomenclature and classifications of this group of diseases used in various laboratories. The diagnosis of fowl leukosis is often made by some pathologists to indicate such conditions as lymphocytoma, fowl paralysis, and myelocytoma. In many laboratories established for the sole purpose of furnishing a routine diagnostic service the factor of economy limits the time and effort that may be expended in arriving at a diagnosis. The diagnosis of fowl leukosis should be supported by adequate study of the tissues, especially histological preparations of the bone marrow and other organs noted to be affected, and stained blood smears when it is possible to obtain them.

Jármai (99) expressed the belief that fowl leukosis was increasing from year to year. He cited the data of Kitt (121) from observations made in Munich:

Year	Number of Necropsies	Cases of Leukosis	Percent of Necropsies
1926	251	17	6.7
1927	447	56	12.7
1928	339	74	20.8
1929	456	125	26.9
1930	372	96	26.6

(Undoubtedly these data include lymphocytomas and myelocytomas as well as fowl leukosis, for Kitt made no etiological distinction between these conditions and classified them as a group.)

A recent report by Goss (90a) on the study of 7408 birds which died among a population of over 24,000 chickens in six different poultry flocks indicates the seriousness of neoplastic disease in the chicken. Tumors were encountered in 1445 (19.51 percent) of the birds necropsied. He found that "tumors composed of leucotic cells (both lymphocyte and myelocyte-like cells) accounted for 13.38 percent of the losses."

Jármai's (99) observations in Hungary are also of interest in this connection:

Year	Number of Necropsies	Cases of Leukosis	Percent of Necropsies
1918 to 1924	722	5	0.7
1925 to 1928	762	6	0.7
1929	304	7	2.3
1930	598	30	5.0
1931	396	24	6.0
1932	157	7	4.0
1933	154	9	5.8

Fowl leukosis in its spontaneous form has usually been observed in birds over six months of age and to affect only relatively few individuals of a flock at any given time (Feldman and Olson 63). An unusual situation was encountered by Hamilton and Sawyer (92) in which 35 of a group of 108 chicks 30 days old and 18 of 123 chicks 39 days old became affected with the disease within a period of two weeks.

There appears to be some relationship between the season of the year and the occurrence of the disease. Ellermann (35) stated that in Denmark it appeared more frequently in the first quarter of the year. Kitt (121) and Lüttschwager (130) observed it more frequently in the autumn, winter, and spring months in Germany. In Japan it appeared in the late spring (Matsubara 139). Jármai (97) and Jármai, Stenszky, and Farkas (105) in Hungary observed the disease more often in the autumn and winter months. It is of interest in this connection that Engelbreth-Holm (52) has pointed out a seasonal variation in the occurrence of acute leukemia in man. Of 95 cases in the Copenhagen hospitals there were twice as many in the winter season as in the summer. The seasonal difference was much more marked in adults than in children.

TRANSMISSION OF FOWL LEUKOSIS

The inciting factor or factors which cause fowl leukosis in its spontaneous form are not known in spite of much experimental work. Fowl leukosis seems to occur much more frequently in some breeds of fowls than in others and it apparently occurs more frequently in some strains of a breed than in other strains of the same breed (Feldman and Olson 63). Experimental attempts to transmit the disease under natural conditions in which susceptible birds have been placed in contact with diseased ones have been uniformly negative (Jármai 99).

Jármai (97) demonstrated that the urine and feces from an infected bird were not capable of producing the disease. Engelbreth-Holm (47, 49) was unable to infect fowls by injecting whole leukotic blood into their stomachs by means of a stomach tube.

Relation of Ectoparasites

The possibility that blood-sucking parasites may act as intermediary agents in the transmission of fowl paralysis has received some attention. This aspect was investigated in experiments by Ellermann (cited by Andersen and Bang 2) with *Cimex leticularis*, by Andersen and Bang (2) with *Dermanyssus avium*, and by Jármai, Stenszky, and Farkas (105) with *Argas* species. All of these investigators obtained negative results. Recently, Gibbs (88) reported an experiment in which there appeared to be transmission of "myeloleukosis" from diseased to healthy birds by means of *Dermanyssus gallinae* with which the birds were infested. This experiment was repeated after the animal quarters were cleaned and the factor of the presence of mites removed with the result that there still was apparent transmission of the disease to the healthy birds although a somewhat smaller number became affected. Johnson (109) has reported the successful transmission of the lymphomatosis agent with *Dermanyssus gallinae* acting as an intermediate carrier.

Although Jármai, Stenszky, and Farkas (105) found the parasites (*Argas* species) of no signifance in the infection of chickens in a natural way, they could reproduce the disease in fowls by injecting material prepared from ticks which had previously engorged themselves on a sick bird. They found, in this way, that the agent of fowl leukosis would remain viable for 25 days in the body of the parasite. Jármai stressed the fact that these parasites could introduce but a small quantity of infective material which would be received in the subcutaneous tissues, a route not likely to result in successful inoculation (Engelbreth-Holm 47). It was also considered possible that the agent in the engorged tick would lose its potency before a new host was attacked.

Ratcliffe and Stubbs (167) noted that the transmissible agent of fowl leukosis would survive at least three hours in the stomach of the mosquitoes, *Culex pipiens* and *Ades egypti*. They were not able to demonstrate transmission of the disease by alternating the feeding periods of these mosquitoes on leukemic and healthy fowls. These workers likewise found that *Dermanyssus gallinae* would not act as an intermediary transmitter of the disease. In their experience the transmissible agent contained in the mosquitoes and mites was inactivated in 24 hours.

Transmission through the Egg

Jármai, Stenszky and Farkas (105) investigated the possibility of transmission of the disease from a sick hen to chicks raised from the eggs laid by her during her illness. Twenty chicks were hatched from such eggs. Two of these were killed at the time of hatching to determine whether the agent was present in their blood, twelve lived to be one year or more of age, and the others died of intercurrent disease. None of the chickens showed evidence of leukosis and the agent was not demonstrable in the day-old chicks.

Experimental attempts to infect eggs during the incubation period have been interesting. According to Jármai, Stenszky, and Farkas (105), the transmissible agent soon lost its potency in the chicken egg at incubator temperature. An experiment was reported by Jármai (98) in which he injected the agent of leukosis into eggs on the first, fifth, eighth, twelfth, and thirteenth days of incubation. Only healthy chicks were hatched from the eggs which received injections up to and including the eighth day of incubation, whereas chicks with leukosis were hatched from the eggs infected with the agent after the tenth day of incubation. As pointed out by Jármai, the myeloid tissue of the bone marrow is developed on the tenth day of embryonic life (Dantschakoff 29). Jármai considered this as evidence that the agent of transmissible leukosis was not capable of development independent from bone marrow tissue. It is of interest that Furth and Breedis (84) found that their Strain 1 fowl leukosis agent (pure erythroblastic and granuloblastic leukosis) would survive for at least thirty days in a tissue culture which contained mononuclear cells presumed to be myeloblasts, whereas the agent perished in a culture composed of sarcoma cells only.

Van den Berghe and d'Ursel (206 b) have hatched chicks from eggs in which the leukosis agent was being carried in serial passage on the chorio-allantoic membrane. A total of six chicks was hatched from eggs that received blood of embryos or embryo emulsion containing the leukosis agent after from one to four serial passages on chorio-allantoic membranes. Five of these chicks had changes of the blood characteristic of leukosis and died from 8 to 19 days after hatching. The sixth chick lived only four days. Blood from two of the leukotic chicks produced typical leukosis in chickens into which it was injected. The five leukotic chicks had a paralysis of the legs, which developed on either the first, second, or third day after hatching. These workers suggest this as evidence of the ability of the leukosis agent to cause fowl paralysis. They do not describe the gross or microscopic anatomy of the nerve tissue and, therefore, this suggestion must await further evidence.

Experimental Transmission

Leukosis has been transmitted from a bird ill with the disease to a susceptible bird by the use of whole blood, blood plasma, ascitic fluid, or emulsions of the organs of the diseased bird (Ellermann and Bang 45, Ellermann 42, Schmeisser 177, Bayon 7, Furth 69, 70, and 71, Jármai 97, Engelbreth-Holm 47, Olson 155, Oberling and Guérin 146, and Nyfeldt 142). These materials containing the inciting agent have been introduced into the recipient by either intravenous, subcutaneous, intramuscular, or intraperitoneal inoculation and have produced the disease. Wakamatsu (209) found the infective agent to be present in brain tissue but not in the bile of affected chickens. He also reported that in some instances it was possible to infect chickens by placing material containing the agent either on the conjunctiva or on the rectal mucosa, but that inoculation into the anterior chamber of the eye was without effect. Wakamatsu used but a small number of experimental birds and his experiments should be repeated with larger groups of animals in order to verify these points. Hamilton and Sawyer (92) reported that application of infective leukotic material to scarified mucosa of the cloaca failed to produce the disease. When the material was introduced into the bursa of Fabricius 20 percent of the inoculated birds developed leukosis.

The amount of whole blood or plasma necessary to reproduce the disease in a susceptible fowl may be very small. Furth (73, 74) has successfully infected chickens with 0.000001 cc. of blood plasma or 0.00001 cc. of cell suspension. Engelbreth-Holm (48) likewise found 0.00001 cc. of leukemic blood capable of producing leukosis but attempts with smaller amounts were unsuccessful. In Furth's experience (74) the successful transmission of the disease with blood plasma ranged from 20 to 28 percent of the fowls injected, whereas cell suspensions yielded success in 33 to 71 percent of the fowls injected. Jármai (97) found that the leukemic cells in a 1:12,000 dilution were still capable of producing the disease.

Many breeds of domestic chickens have been found to be susceptible to the agent of fowl leukosis. It is not unreasonable to presume that all of the various breeds of *Gallus domesticus* may be artificially infected with transmissible leukosis. Age appears to be one determining factor in the susceptibility of chickens to leukosis. Younger fowls seem to be more susceptible than older ones as indicated by a higher percentage of successful inoculations and a shorter incubation period (Stubbs and Furth 192, Stubbs 189, and Engelbreth-Holm and Rothe Meyer 56, 57).

Types of Disease Produced

The majority of investigators have come to agree that the agent of transmissible fowl leukosis will produce two forms of the disease; namely, erythroblastic leukosis and granuloblastic leukosis. Exception must be made for the production of sarcoma with this agent under special experimental conditions which will be discussed later. It is also quite generally accepted that the inoculation of blood from a fowl ill with erythroblastic leukosis may result in the production of either erythroblastic, granuloblastic, or mixed leukosis. The converse is likewise true; that is, granuloblastic or mixed leukotic blood may produce any of these three types of disease upon inoculation into susceptible birds. Furth (71) reported that in 30 transmission experiments, in which 377 chickens received the transmissible agent of leukosis, 34 developed myeloid leukosis (granuloblastic leukosis), 36 erythroleukosis (erythroblastic leukosis), 25 a mixed leukosis, 6 lymphoid leukosis (lymphocytoma), and 4 myeloma. His control data involved 193 chickens among which were two with lymphoid leukosis (lymphocytoma). Stubbs and Furth (193) utilized two groups of 25 chickens which were housed and cared for under identical conditions. One group was inoculated with blood from two chickens affected with fowl leukosis (one erythroblastic and the other granuloblastic leukosis), with the result that 13 developed leukosis within four to ten weeks after inoculation. The other group was not inoculated. Lymphocytoma was found in one fowl from each group. None of the birds of the uninoculated group developed leukosis. Olson (155) described three strains of leukosis which had been inoculated into 173 chickens. Of this group 106 or 61.3 percent developed leukosis, 69 having erythroblastic leukosis, 29 granuloblastic leukosis, and 8 incipient leukosis. Nyfeldt (142) reported the development of a strain of leukosis in which the granuloblastic form was the usual type of disease produced. The strain originated from a case of spontaneous myeloid (granuloblastic) leukosis. Transmission of the disease was effected by the use of whole leukemic blood. It is of interest to note that of 250 chickens inoculated, 49 died shortly thereafter. No explanation of these sudden deaths was given and they were not considered in the results of the experiments. Among the remaining 201 birds, leukemic myeloblastosis (granuloblastic leukosis) developed in 105, and aleukemic myeloblastosis in 8. In some cases of myeloblastosis, erythroblastic changes were present (mixed leukosis). Nyfeldt was not able to confirm the usually observed higher degree of susceptibility of young chicks to the agent of leukosis with this strain.

Jármai's (99) strain of leukosis agent, after the first few passages, always manifested itself as erythroblastic leukosis when used to inoculate chickens in the usual manner. In 1935, Jármai (100) reported the production of fibrosarcoma with tissues (liver, spleen, and bone marrow) from birds affected with his strain of erythroblastic leukosis. The sarcoma developed in the breast muscle of the experimental chickens where the tissue for inoculation was implanted. The tumors did not reach a large size and the experimental life of the birds was short as in each instance erythroblastic leukosis was also present. He was able to transmit the sarcoma through three serial passages after which he discontinued the experiment. Stubbs (191) attempted to repeat this experiment of Jármai using Furth's Strain 1 agent, with the result that in 110 chickens receiving either leukotic blood or organs intramuscularly, 61 instances of leukosis occurred with no evidence of local tumor formation.

Five different strains of experimental leukosis have been developed by the Danish workers. Engelbreth-Holm and Rothe Meyer in 1935 (58) gave a general review of their observations on the 5500 chickens inoculated with these five strains. Erythroblastosis, myelosis, sarcoma, or a mixture of these conditions developed in 3100 of these chickens. These strains have been somewhat variable in respect to the types of disease produced. Strain R gave origin to 1255 cases of erythroblastic leukosis, one case of granuloblastic leukosis, and nine cases of mixed leukosis; Strain T divided itself into two branches, one of which produced only erythroblastic leukosis whereas the other branch (T_1) brought about granuloblastic leukosis as well; Strain E-S produced both erythroblastic leukosis and sarcoma; and Strains Ø and AA gave rise only to pure erythroblastic leukosis. The predominating form of disease in all strains was the erythroblastic type. Engelbreth-Holm and Rothe Meyer (59) have emphasized that age of the experimental animal was a decisive factor in the question of susceptibility; birds less than three months old were much more susceptible than those over six months old. They have noted relatively few instances of granuloblastic leukosis in birds over six months old.

Rothe Meyer and Engelbreth-Holm first reported on Strain E-S in 1933 (171) at which time their experiments concerned the use of 202 chickens. In this group of inoculated birds 72 cases of erythroblastic leukosis developed, of which only 14 were typical and the remainder were of the anemic type. Fibrosarcoma developed in 60 chickens and 21 were affected with a combination of fibrosarcoma and erythroblastic leukosis. In two instances granuloblastic leukosis developed in association with fibrosarcoma. The transmissible tumor was composed of spindle-cells and showed typical malignant invasion of the muscle structure adjacent to the site of inoculation. Metastases to the visceral organs were very infrequent. This strain of leukosis had its origin in a bird affected with granuloblastic leukosis and multiple sarcomatous tumors, and in the first few animal passages there appeared to be two agents responsible for these dissimilar processes. Intravenous inoculation of the blood of the original bird produced erythroblastic leukosis in the first four animal passages, but in the fifth passage two cases of sarcoma as well as two cases of erythroblastic leukosis were produced. Transplantation of the original sarcoma produced sarcoma in five of ten experimental birds so inoculated. Engelbreth-Holm and Rothe Meyer (58) have reported that a leukosis-producing agent could not be completely separated from a sarcoma-producing agent in Strain E-S, although it was generally true that intravenous inoculation resulted in the development of leukosis and intramuscular inoculation was followed by local formation of sarcoma. The existence of only one agent in this strain was indicated by the fact that erythroblastic leukosis was produced without sarcoma for 43 animal passages and then, from the last animal passage, sarcoma was produced by intramuscular inoculation. Furthermore, by transplantation, the sarcoma of this strain was carried through 28 animal passages and then erythroblastic leukosis was produced by intravenous inoculation of blood after the last animal passage.

Uhl, Engelbreth-Holm and Rothe Meyer (206) reported on the production and pathogenesis of the sarcomas associated with Strains T_1 and R. The first 160 passages of Strain T_1 and the first 126 passages of Strain R yielded only erythroblastic leukosis. Subsequently subcutaneous and intramuscular inoculations with material of these strains brought about local sarcoma development. These workers were able to produce sarcoma by subcutaneous inoculation of either washed leukotic blood cells or leukotic plasma although the incidence of success was low. The sarcomas thus produced were slow and steady in growth and of a "polymorphous fusocellular type" in which the type cell was a very immature fibroblast. No differences of histological structure were noted between the sarcomas produced by the two Strains, T_1 and R. Sarcomas of Strain E-S grew much more rapidly. Transplants of sarcomas of Strain T_1 gave rise to erythroblastic leukosis, sarcomas, and combinations of the two. The transplanted sarcomas were feeble in growth and could not be successfully retransplanted. The sarcomas of Strain R could not be transplanted.

Strain 13 described by Stubbs and Furth (195) originated in a chicken inoculated with their Strain 1 of erythroblastic leukosis and in its subsequent passages produced sarcoma (endothelioma) and erythroblastic leukosis. Kabat (118) has studied a polysaccharide obtained from the mucinous material in two tumors produced by Furth's Strain 13 agent. The chemical properties of this polysaccharide are similar to those of a polysaccharide obtained from other mucinous material, namely, the vitreous humor, umbilical cord, synovial fluid, and the mucoid hemolytic streptococcus. Stubbs and Furth (195) were unable to arrive at any definite conclusions regarding the agent of this strain, but considered the following possibilities: (a) Strain 13 consisted of a single agent which was capable of producing both sarcoma (endothelioma) and erythroblastic leukosis and the agent was either of spontaneous occurrence in the first chicken to become affected, or developed as a variant of Strain 1 agent. (b) Strain 13 consisted of two agents each producing a characteristic reaction. They favored the belief that Strain 13 was a single agent, although they found that implants of the tumor tissue of Strain 13 would grow in chickens resistant to repeated inoculations of pure leukosis agent. Furth (82) has found that he could readily separate his Strain 1 agent from the Strain 11 agent (which causes fibrosarcoma only) when the two have been inoculated into the same chicken.

The transmissible strain of leukosis developed by Oberling, Guérin, and Boic (151) had an obscure origin. A chicken unsuccessfully inoculated with the filtrate of a Murray-Begg fowl endothelioma died with primary carcinoma of the liver six months after inoculation. Two chickens were inoculated with material from this bird and, six months later, one died with leukosis and a retrorenal myeloma. The transmissible strain of leukosis was carried on from this individual. Of 104 chickens inoculated with blood or emulsions of the organs, 54 died with erythroblastic leukosis of which number 19 cases were associated with a granuloblastic reaction and 11 cases developed a transient erythroblastic leukosis. Subsequent passage of this agent with the use of blood or tissues kept in glycerin and inoculated intramuscularly into experimental birds has in some instances provoked a neoplastic reaction in the connective tissues (144, 145). The neoplasms encountered were fibroblastic, spindle-cell sarcomas, rich in collagen fibers and sometimes showing myxomatous changes. In two cases epithelial neoplasms developed at the edge of a sarcomatous mass, which were believed to be the result of action of the same agent. Morelli and Vercellone (141 b) have observed the development of fibrosarcoma in a chicken injected with material of the Oberling and Guérin strain of leukosis agent.

Oberling and Guérin (146) describe their experiments with a bird (A 414) which had developed erythroblastic leukosis following inoculation with their strain of the agent. Blood, bone marrow, or spleen tissue of the bird was preserved in glycerin and used as inoculum. Of the 22 chickens inoculated, 7 developed sarcomas, 3 of which metastasized. A total of 15 chickens of the group (including the seven with sarcoma) died with leukosis. Oberling and Guérin (147) describe in another report the results following inoculation of material from these birds with tumor. Five birds received intramuscular inoculations of fragments of the above-mentioned sarcomas. A sixth chicken received an intravenous inoculation of fresh blood from a leukotic bird with a sarcoma. All six of these birds showed hyperplastic reactions of the reticulo-endothelium in the liver, spleen, lungs, and bone marrow. Although there was a disturbance of the blood in all instances, only two showed the typical reaction of erythroblastic leukosis. Oberling and Guérin (146) report that they attempted to graft eight of the sarcomas to 32 experimental chickens but obtained only erythroblastic leukosis. More recently they (149) have reported that intracutaneous inoculation of fresh leukemic blood was more likely to produce sarcoma in chickens than intramuscular injection and that large doses (0.5 cc.) were more likely to induce tumor formation than were smaller amounts. Their attempts to modify the agent of their strain and make it more sarcomogenic or histiotropic in the presence of embryonic tissue pulp, infusorial earth, and thorotrast were negative (144).

Storti and Zaietta (188) have conducted some interesting experiments which indicate the potentiality of a leukosis strain to induce spindle-cell sarcoma formation. Although they do not mention the source of the strain with which this work was conducted, it may be assumed that it was that of Oberling and Guérin for in an earlier report (185) Storti mentions having worked with this strain for several years. Three sarcomas were observed in a group of 35 chickens which had received glycerinated leukotic blood, 6 in a group of 45 chickens which had received organ suspensions in glycerin, and 10 in a group of 30 chickens which had had a doubly ligated blood vessel filled with leukotic blood implanted in their pectoral muscle. In some instances the blood vessels, a 1 to 2 cm. portion of the jugular vein or aorta of a healthy chicken, were used fresh; in others the vessels had been held in the ice box; and in still others the vessels had been fixed in formaldehyde solution. In none of the 19 cases of tumor formation were metastases observed nor was it possible to transplant the sarcomas, for the birds receiving the transplant died of leukosis before the transplant could become established.

Pikowski and Doljanski (165) described a spontaneous case of erythroblastic leukosis in which there was also disturbance of the granuloblastic elements. Four chickens received intravenous inoculations of blood from this case. One (chicken 86) died seven weeks later with sarcoma-like foci in the spleen, hyperplasia of the periportal lymphoid elements of the liver, proliferation of the vascular endothelium in the liver, and hyperplasia of the bone marrow; the blood showed no abnormal changes. An emulsion of the liver and spleen of chicken 86 gave rise to a slow-growing fibrosarcoma when injected into the pectoral muscles of other experimental birds. This tumor was carried for five serial passages without change, except for a somewhat more rapid growth. Intravenous inoculation of blood and organ suspensions from chicken 86 produced an anemia with moderate immaturity of the erythrocytes and granulocytes and changes of the cellular reticulum of the liver, spleen, and bone marrow as well as proliferative changes of the vascular endothelium in three chickens.

Troisier (202) studied the transmissibility of 23 cases of spontaneous sarcomatosis of the chicken. The neoplasms were transmissible in six of these cases and he believed that in some of these cases the neoplasms were associated with leukosis. This association was, however, not constant and the possibility of spontaneous occurrence of leukosis was not entirely eliminated.

Troisier and Sifferlen (203) review this work and express the belief that a single agent may be responsible for both sarcoma and leukosis in these experiments. This cannot be generally true as Furth (82) has shown that the agent of pure transmissible erythroblastic leukosis (Strain 1) can be separated from the agent of a fibrosarcoma (Strain 11) when both are inoculated into the same chicken. Furthermore, Furth (81) has submitted evidence to indicate that the mixed osteochondrosarcoma and lymphomatosis producing agent (Strain 12) and the Strain 2 agent are distinctly different, although the Strain 12 agent was derived from a chicken previously inoculated with the Strain 2 agent.

McIntosh (140) induced sarcomas in chickens by injections of tar and lard. The tumors thus produced were then transmitted through successive generations. In one series of experiments leukosis was observed to be associated with the disease in its earlier passages, but after the second or third passage the tumor appeared to settle into a single type and the leukotic character disappeared. McIntosh and Selbie (141) describe a further series of transmission experiments with tumors induced in the chicken with tar. In one series the first passage of the induced tumor produced a reaction in one of the inoculated birds which may be considered a form of myelocytoma. The tumor masses in the case of myelocytoma were adjacent to the sternum and ribs and were composed of undifferentiated cells and myelocytes, while the blood from the heart contained many myeloblasts and myelocytes. There was no evidence of sarcoma in this animal. In the third passage the tumors were composed of a mixture of myeloid and connective tissue elements, and in subsequent passages the tumors were composed of only connective tissue elements. McIntosh and Selbie believe that there was an association of two agents in these experiments, each responsible for one of the two types of reactions noted.

Incubation Period and Course

The incubation period is usually considered as the interval between inoculation and the appearance of immature cells in the blood. The length of this period varies with the different strains. Successive animal passage appears to be an important factor in enhancing the virulence of the agent and thereby shortening the incubation period. Ellermann (41) believed that the increase of virulence of the leukosis agent occasioned by successive animal passage was marked more particularly by a decrease in the length of the course of the disease rather than by the ability to produce disease in a higher percentage of chickens. It has usually been stated that the incubation period and the duration period (interval from the time of first evidence of disease to death) of granuloblastic leukosis are shorter than those of erythroblastic leukosis. Engelbreth-Holm and Rothe Meyer (59), however, report that 1210 chicks affected with erythroblastic leukosis produced by the agents of Strains R, T_1, and E-S lived for an average of 12 days after inoculation, whereas 127 chicks affected with granuloblastic leukosis produced by the agents of strains T_1, Ø, and AA lived for an average of 32.5 days.

Furth's (72) Strain 1 of leukosis showed an average incubation period of 47 days (13 being the minimum and 124 the maximum) and an average duration period of 19 days. The length of life after inoculation was found by him to vary from 21 to 204 days. One chicken with experimental leukosis has been observed to live for 552 days after inoculation during which time there were remissions from the disease (Olson 155). In Furth's (74) studies on the concentration of the agent in the blood plasma he observed a prolongation of the incubation period when inoculations were made with small amounts of leukotic plasma.

The disease-producing ability of the leukosis agent studied by Hamilton and Sawyer (92) was particularly pronounced, as in the 12 serial passages of the agent the longest interval between inoculation and death was only 27 days, the shortest 5 days, and the average 14.7 days. In addition, relatively few birds were found to be resistant to the agent.

Jármai (102) has recently published some interesting figures which indicate the increase in virulence of his strain of leukosis agent associated with animal passage. These are:

Year	Average number of days from inoculation to death
1930	20
1931	15
1932	15
1933	14
1934	12
1935	12
1936	12
1937	11

Engelbreth-Holm and Rothe Meyer (54) noted early in their experiments with one of their strains that the incubation period was longer and the anemic form of the disease more common in the fall and winter months than at other seasons. The more severe form of disease developed in the summer months. More recently, they (59) found that the seasonal variation had been manifest in adult birds for three successive years, but that no such variation of susceptibility could be detected in birds less than three months of age. The maximum of 82 percent successful inoculation of adult birds took place in April and May and the minimum of 40 percent occurred in October and November. They have investigated several possible reasons for this seasonal variation of susceptibility, including the matter of green feed in the diet, and the effect of more sunlight during the summer. Neither of these factors seemed to be concerned. The Danish workers also considered the possibility of hormonal variation with the season. Engelbreth-Holm, Rothe Meyer, and Uhl (61) have since reported that growth hormone did not influence the rate of development or character of disease in chickens inoculated with their Strains E-S or T. In one experiment they demonstrated that the hormone preparation was active as the birds receiving the hormone showed a greater weight increase than the control birds. Gonadotropic hormone did not inhibit the development of leukosis, but it did partially inhibit the growth of sarcomas produced by the Strain E-S agent when administered either alone or in conjunction with extract of the pineal body. Jármai (102) noted that the length of time between inoculation and death of the experimental animal was usually longer in the first half of the year than in the last half of the year. This was especially noticeable during the years 1930 and 1931 when the average of this period was still 15 days and the variation was commonly one or two days.

After the period from inoculation to death had become shortened to 14 days or less the effect of the season could no longer be noted.

Crank and Furth (26) have brought about death of experimental birds in two or three days by transfusing them with large amounts of leukemic blood from birds diseased with Furth's Strain 1 agent. The brief and fatal course of the disease was apparently due to the autonomous growth of the inoculated leukemic cells in the new host.

Once a form of disease becomes manifest, that form usually persists until the death of the affected fowl. There are, however, instances in which a transition from one form of leukemic process to another occurs in the course of the disease (Jármai 99, Olson 155).

Spontaneous recovery after development of leukosis in experimental birds has been found infrequently by various investigators. There were only four instances of spontaneous recovery observed in 98 cases of experimentally produced leukosis (Olson 155). In one of these recovered birds the infectivity of whole blood was demonstrated during the time that changes were still evident in the blood. Oberling, Guérin, and Guérin (152) stated that the incidence of spontaneous recovery following inoculation with a strain developed by them was less than 10 percent, whereas they observed no recoveries following inoculation with a strain which they had received from Engelbreth-Holm.

Storti and Zaietta (187) have observed that an induced anemia in chickens had the effect of increasing the number of successful inoculations and also of shortening the incubation period and the subsequent course of the disease. Their experimental birds were inoculated with the agent of leukosis after the count of red blood cells and the hemoglobin value had fallen to about half the original normal levels. The state of anemia was induced either by repeated bleeding or by the repeated intravenous injection of 1 percent saponin solution. In the case of acute anemia, from 40 to 50 cc. of blood was removed at one time from birds weighing 1000 to 1400 grams; and in the case of chronic anemia, 10 to 15 cc. of blood was removed daily for eight to ten days. They also noted that, in four instances in which the experimental disease was pursuing a chronic course, removal of blood led to the development of the blood picture of acute leukosis in three or four days and to death within a week. Control animals, that is birds affected with the chronic form of the disease but not bled, continued to live for two or three months.

Wallbach's (212) claim that he succeeded in changing erythroblastic leukosis (produced with a strain received from Thomsen in Denmark) to granuloblastic leukosis by the administration of arsylene or benzol is not convincing. He observed a transitory granulocytosis in normal chickens as well as in leukotic birds following administration of these substances.

Pathogenesis

The site of irritation of the exciting agent of fowl leukosis and the mode of development of the disease are problems difficult to solve. In related fields considerable work has been done in attempts to clarify the histogenesis of the Rous sarcoma and similar tumors of the chicken. It is rather generally accepted that the agents of these tumors are initially localized in the tissue of an inoculated bird by cells of the macrophage type, but the subsequent role of these cells is not yet settled. Some believe that the macrophage is then converted into the type cell of the specific tumor whereas others believe that the macrophage liberates the agent which is then capable of stimulating the type cell of the tumor into a state of malignancy. Foulds (68) and Levine (129) have reviewed the extensive literature on this question and their articles should be consulted for details of this aspect.

Crank and Furth (27), Rothe Meyer and Engelbreth-Holm (170), Storti and Brotto (183), and Ruffilli (174 d) have demonstrated the agent of fowl leukosis in the blood of recipients immediately after inoculation. Most if not all of the agent disappeared within 24 hours after inoculation, and it was found again in the blood almost simultaneously with the appearance of immature cells.

Ruffilli (174 d) observed that the whole blood or blood cells were infective for a longer period of time immediately after intravenous inoculation with the leukosis agent than was the blood plasma. This probably was due to simple physical adsorption of the agent to the blood cells. He also found that the bone marrow was infective as early as three hours after intravenous injection of the agent, but infectivity was more readily demonstrable after 24 hours.

Van den Berghe and d'Ursel (206 a) have indicated that the agent of leukosis, although present in all the blood constituents, may be more concentrated in the immature blood cells than in other fractions of leukotic blood. Their method of study was to use leukotic bloods with different relative amounts of immature cells. The plasma and cells were separated and one portion of the cells was laked by freezing at —10° C. The plasma was generally found to be the weaker in virulence. Laking of the cells had no effect on increasing the activity of the inoculum preparations.

Ratcliffe and Furth (166) studied the changes in the tissues of fowls killed at various intervals after they had been inoculated with cell-free filtrates, with washed cells, or with whole blood obtained from leukotic birds. The first change observed in chickens receiving cell-free material was a hyperplasia of the erythroblastic cells in the marrow sinuses, which was followed by the appearance of immature cells in the blood. Chickens inoculated with cell-containing material showed leukemic changes in the blood at a time when the capillary bed of the bone marrow was only partially filled with erythroblasts. Only a slight granuloblastic hyperplasia was observed. Three possible explanations of the hyperplasia were considered: first, irritation of preexisting basophilic erythroblasts; second, stimulation of the reticulo-endothelial cells of the marrow sinusoids; and third, a neoplastic growth of the inoculated cells lodging in the bone marrow. Ratcliffe and Furth favored the first of these theories. No explanation of the manner of development of granuloblastic leukosis was given, although a selective action of the inciting agent of the disease was suggested. Engelbreth-Holm and Rothe Meyer (58) offered an explanation that certain chickens are predisposed to a certain type of the disease and that passage of the agent through these chickens enhances the ability of the agent to produce that specific type of reaction. This idea was substantiated in their Strain T_1 which they observed to separate into two branches, one of which was entirely erythroblastic in character, whereas the other was preponderantly granuloblastic.

Ellermann (42) believed that the granulocytic hematopoiesis was different in granuloblastic leukosis than under normal conditions. Under normal conditions the process proceeds in the following manner: the myelocyte divides to form other myelocytes and some divide to form metamyelocytes and these in turn form the polynuclear cell (heterophil). The pathological development of the granulocytes in granuloblastic leukosis, he believed, began with the much more immature myeloblast which developed into the poikilonuclear cell after passing through the stage of the metamyeloblast. He regarded this poikilonuclear cell as analagous to the leukoblast of Pappenheim.

Autonomous growth of the leukemic cells in granuloblastic leukosis was demonstrated by Crank and Furth (26). They transfused 15 chickens with 15 to 30 cc. of leukemic blood obtained from a bird affected with the granuloblastic form of the disease. The result was that nine birds died within two to three and a half days after inoculation. The count of white blood cells in these chickens increased greatly during this relatively short time. Many of the transfused cells were removed from the circulation in the capillary bed of the spleen, liver, and lung. Earlier work (Crank and Furth 27) had indicated that the retained cells multiplied in these sites by autonomous growth in the susceptible birds and that in resistant fowls they were disposed of by the phagocytes of the organ involved.

As a result of experiments in which chickens received intravenous injections of India ink to blockade the reticulo-endothelial system previous to inoculation with leukosis material, Jármai, Stenszky, and Farkas (105) came to the conclusion that the leukosis cells are not descendants of the reticulo-endothelial system. The circulating leukotic cells were free of ink particles even though the livers and spleens of these birds were entirely black with the ink.

Storti and De Filippi (185) could find no evidence of participation of the phagocytic elements of the reticulo-endothelial system in the formation of the extramedullary myelopoietic foci in leukotic fowls. Their experiments were carried out in chickens in which leukosis was produced by the Oberling and Guérin Strain of the leukosis agent. The birds received intravenous injections of India ink to mark the phagocytic cells and were killed at various stages of the disease. Storti and De Filippi came to the conclusion that the foci of leukotic cells in tissues other than the bone marrow represented local proliferation of cells originally derived from the marrow.

Engelbreth-Holm (51) found that the nuclei of the primitive erythroblastic cells from the bone marrow of leukotic chickens have a significantly greater average diameter than the nuclei of comparable normal cells, which feature he believes indicates the neoplastic character of the leukotic cells.

Magat and Magat (132) have noted a characteristic absorption in the spectrum of leukemic blood from chickens which had received an intravenous injection of a colloidal lecithin and perhydrite mixture. This absorption of the spectrum of blood was not noted after injection of the complex into normal birds or birds affected with avian pest, diphtheria, or acute anemia. There was an increased coagulability of the blood following administration of the material which was brought about by smaller doses in leukotic fowls. Magat and Magat concluded that their experiments showed a disturbance of the physio-chemical properties of the blood in leukosis.

The various reactions produced by the different strains of agents causing transmissible fowl leukosis may be regarded as an indication of selective action on different developmental levels of descendants from a common mesenchymal cell (Engelbreth-Holm and Rothe Meyer, 58). Thus they suggest that the so-called complex strains (Strain E-S of these workers and the leukosis-sarcoma strain of Oberling and Guérin) attack a cell derived from the mesenchyme which has the potentiality of forming either blood cells or connective tissue. The complex strains 2 and 13 of Furth may also belong to this group. Further, they believe that the agents producing both erythroblastic and granuloblastic leukosis act upon a stem cell common to both and that the agent giving rise to pure leukosis stimulates a cell already differentiated to the extent that it can form only cells of the erythrocytic or granulocytic lineage. They carry on with their hypothesis and suggest that the agent giving rise to the Murray-Begg endothelioma acts upon a cell of the angioblastic series of this group and the agents of the Rous and similar type tumors exert their effect on the cells of the fibroblastic series. Jármai (100) explains the action of his strain of leukosis agent, which produced sarcoma after having produced only erythroblastic leukosis for years, by endowing the agent with a predominant hemotropic tendency and also a histiotropic tendency that was subdued by the usual intravenous mode of inoculation. Such a combination of properties is not found in all pure strains of agent causing erythroblastic leukosis, as was indicated by the failure of Stubbs (191) to induce sarcoma formation. Stubbs injected leukotic blood of Strain 1 into the muscles of a large series of experimental chickens, with erythroblastic leukosis as the only result.

The work of Jordan (112), indicating that the small lymphocyte of avian blood or bone marrow may be a potential hemoblast giving rise to any of the blood cells in a strictly monophyletic manner, may explain the mode of action of Furth's Strain 2 agent in producing lymphomatosis. From this point of view, however, one cannot readily explain the lack of lymphomatous reactions in the other leukosis-sarcoma strains reported.

THE TRANSMISSIBLE AGENT

Filtrability

Ellermann and Bang's (45) discovery that the etiologic agent of transmissible leukosis could pass through filters impervious to bacteria has been confirmed by many investigators among whom are Hirschfeld and Jacoby (94), Andersen and Bang (2), Battaglia and Leinati (6), Jármai (97), Furth and his collaborators (71, 83, 85), and Oberling and Guérin (146). The experience of Ellermann (35) was that the filtrate would infect 16 percent of the chickens inoculated with it. Andersen and Bang (2) reported that 25 percent of chickens inoculated with filtered material would develop the disease. Jármai (97) observed that 10 percent and Furth (71) that 12.7 percent of birds inoculated with filtrates became leukotic. According to Furth and Miller (85) the inciting agent will readily pass through all types of silicious filters. They found that the incubation period of the disease was somewhat longer when it was produced by filtrates than when it was produced by unfiltered material. By filtration through collodion membranes the agent has been shown to be of about the same size as bacteriophage and smaller than 250 millimicrons (Furth and Miller 85). Although Jármai, Stenszky, and Farkas (105) were unable to pass the agent through a relatively coarse Berkefeld filter, they did pass it through a Zsigmondy-Bachman membrane filter of a pore size which permitted the passage of egg albumin (20 to 100 millimicrons). Johnson and Bell (110) reported that the leukosis agent was found to pass through membranes whose pore size was between 100 and 400 millimicrons although these workers extend the conditions caused by the filtered agent to include lymphocytoma and fowl paralysis.

Stern and Kirschbaum (182) have studied the sedimentation rate and physicochemical properties of Furth's Strain 1 leukosis agent which had been purified by repeated slow- and high-speed centrifugation in an air-driven centrifuge. The agent was obtained from the bone marrow which was a rich source of the macromolecular material with which they were dealing. One gram of bone marrow yielded 11 milligrams of macromolecular material. This material was found to produce the disease in four of 19 chickens into which it was inoculated. The macromolecular material was found to contain 9.5 percent nitrogen, to give positive tests for thymonucleic acid, and hemin, and to possess cytochrome oxidase and catalase activity. The size of the agent was estimated to be 72 millimicrons, the particle weight to be 2.6×10^{-16} and the "molecular" weight to be 146×10^6. These characteristics of the fowl leukosis agent resembled very much those of the agent of the Rous chicken sarcoma and also those of a material derived from chicken embryo when treated in a similar manner. Only traces of the macromolecular material could be secured from normal bone marrow under the same conditions.

Biological Properties

Ellermann (35) found that the infective agent would remain viable when kept for a week in a refrigerator. Hirschfeld and Jacoby (94) demonstrated the distinction between the causative agents of leukosis and avian tuberculosis by exposing a mixture of the leukosis agent and avian tubercle bacilli to ice-box temperature for 10 days, after which time the mixture caused only tuberculosis in the inoculated fowls. Jármai (97), however, was able to produce leukosis with emulsions of organs which had been in the ice box for 10 days. Furth (75) found the infective agent resistant to 14 days of exposure to ice-box temperature (4° C.). He also found that it was not inactivated by freezing in liquid air and subsequent thawing. Oberling, Guérin, and Boic (151) stated that their best transfers of leukosis were obtained with leukemic whole blood which had been stored from one to thirty days in the ice box.

The causative agent of fowl leukosis has been shown to be thermolabile by different investigators. In Jármai's (97) experience, a temperature of 56° C. for a half hour served to destroy the agent. Furth (75) found that when leukemic blood was kept at 37.5° C., the capacity to produce the disease was greatly diminished within seven days and was completely lost after 14 days. Oberling and Guérin (146) stated that material kept for two weeks at a temperature of 37° C. was rendered avirulent. Wallbach (211), however, reported that leukotic material would produce disease in 30 percent of inoculated animals after it had been exposed for one hour to 70° C., but that a temperature of 80° C. for one hour completely destroyed the agent. Exposure for 24 hours at 20° C. reduced the virulence of the agent, and after 24 hours at 40° C. the agent produced disease in only 5 percent of the inoculated chickens.

Desiccation experiments on leukemic blood conducted by Furth (75) led him to believe that the process of drying would often lessen or completely destroy the infective power of the blood. He found, however, that once dried, the deterioration of the agent was very slow. In one instance he found that leukemic blood that had been in a dried state for 54 days was still infective. Stubbs (190) reported that dried leukemic blood, sealed in tubes and kept in the ice box for 932 days was capable of producing the disease. Wakamatsu (209) found that the infective agent of a leukosis strain, which he had received from Engelbreth-Holm, was avirulent 58 days after being dried.

Furth (75) observed no decrease in the virulence of leukemic blood which had been preserved in 50 percent glycerin for 104 days as compared with that held in glycerin for 54 days. In either case, however, the incubation period was longer when the disease was induced with glycerinated material than when corresponding amounts of fresh blood were used. Jármai, Stenszky, and Farkas (105) found the agent viable in material kept in glycerin solution for 45 days, and Jármai (102) has noted the weakening effect of glycerin as indicated by the prolongation of the incubation period. Oberling and Guérin (146) reported leukemic blood to be infective after being kept in glycerin solution for 150 days.

The agent of leukosis was not harmed by a three-hour exposure to 0.5 percent phenol solution but was inactivated by a 0.5 percent tannin solution according to Jármai (99). He believed that, in the latter case, the agent was bound to the albumin molecule and precipitated with the tannin solution. More recently, Jármai (102) has submitted evidence to indicate that the agent in the blood of leukotic chickens is more frequently bound with the globulin fraction than with the albumin fraction of the blood. The disease produced with the prepared globulin fraction was characterized by a prolonged incubation period, although the duration of the disease when once established was about 15 days.

The leukosis agent is susceptible to oxidation as is indicated by the work of Engelbreth-Holm and Frederiksen (53) and Ruffilli (174 c). Ruffilli used gaseous oxygen, hydrogen peroxide, and potassium permanganate as oxidizing agents whose destructive action could be hindered or prevented by the presence of cystein, but could not be reversed. Engelbreth-Holm and Frederiksen (53) used gaseous oxygen and found that leukotic plasma could be reactivated by cystein-cobalt, if the oxidation were interrupted before inactivation was complete. Ruffilli (174 c) obtained inactivation of leukotic plasma in the presence of normal chicken erythrocytes when proper conditions of temperature and length of exposure were supplied. Tissue cultures of normal adult spleen, liver, and bone marrow likewise destroyed the agent in leukotic plasma used to nourish the cultures.

The agent of fowl leukosis has been shown to be resistant to irradiation with roentgen rays by the investigations of Jármai, Stenszky, and Farkas (105), Engelbreth-Holm and Rothe Meyer (54), and Forfota (67). Jármai (103) has discussed his own work and the work of others with respect to the resistance to roentgen rays of the agents of leukosis, the agent of the Rous sarcoma, and the filtrable agent of his own strain of sarcoma, and the cells of various transmissible mammalian neoplasms. He has pointed out that the agents of the filtrable fowl tumors and fowl leukosis will withstand an enormous dose of roentgen rays. The Rous sarcoma agent has been exposed to 600 times the erythema dose and the leukosis agent to 240 times the erythema dose without destruction. Fragments of the mammalian tumors (Ehrlich's mouse carcinoma, the Moravek-Jedlickas mouse carcinoma, a transmissible mouse sarcoma initially produced by chemical action, and the Flexner-Jobling rat sarcoma) lost their infectivity after exposure to only 20 erythema doses of roentgen rays.

Wakamatsu (210) studied the effect of treatment of the leukosis agent with a preparation called hepatrat, and the gold, silver, arsenic, and copper salts of detoxin. The effect of such treatment was slight or none. Rothmann's plumbo-dithio-pyridincarbonacid potassium and lead detoxin were found to have a distinct inhibiting action on the agent of fowl leukosis.

Rothe Meyer, Engelbreth-Holm and Uhl (172, 174) have shown that the agent of leukosis present in the blood plasma may be bound to the red blood corpuscles of normal and spontaneously recovered chickens as well as to the red blood cells of pigeons, rabbits, sheep, and man. The corpuscles of such a mixture could not be freed of the agent by repeated washing after the mixture had been allowed to stand for one hour at room temperature. It was further found that ten consecutive adsorptions of leukotic plasma with red blood cells of a normal chicken did not exhaust the leukosis-producing power of the plasma. They believed that this combination of cells and agent was a matter of simple physical adsorption.

Kabat and Furth (118 a) have reported studies on the properties of crude extracts and high-speed centrifugate of the tumors produced by the Strain 13 agent and on the high-speed centrifugate of plasma obtained from birds made leukotic with either Strain 13 or Strain 1 agent (see appended synopsis, p. 48).

The activity of the crude extract was about the same as that of the high-speed centrifugate. The centrifugate of crude tumor extract containing approximately 10^{-5} mg. nitrogen produced tumors at the site of injection in chicks. A carbohydrate-splitting enzyme preparation reduced the viscosity of crude tumor extracts, but had no effect in increasing the activity of the extract.

Centrifugate from 10 cc. serum of a normal chick contained 0.34 mg. nitrogen, although this value varied somewhat in specimens taken from the same chicks at different times. About twice the normal amount of sedimentable material was obtained from serum of a chicken affected with Strain 1 leukosis, and the average amount of serum centrifugate in cases of leukosis produced by Strain 13 was only slightly higher than that from normal serum. Normal chicken and mouse spleens and other human and mouse tissues examined contained large amounts of material sedimentable by high-speed centrifugation. It was thus indicated that the mere presence or amount of centrifugate had no relation to the disease-producing agent. The centrifugate of leukotic plasma or leukotic cell washings (the leukosis being produced by either the Strain 1 or Strain 13 agent) was capable of producing the disease. The centrifuged deposit of the second washing of leukotic cells was feeble in this power, as only two of eleven birds so inoculated with 1:5 dilution became affected with leukosis. The washed leukotic cells were much more active in producing leukosis, and irradiation with 15,000 r of roentgen rays did not significantly reduce this ability, although the cells themselves were destroyed.

The centrifugate of tumor extracts maintained its activity for six months at −60° C., but deteriorated rapidly at ice-box temperature. This deterioration was slightly slowed by the addition of 5 percent of a saturated solution of sodium sulfate or magnesium sulfate. Gum acacia, tumor polysaccharide or supernatant fluid were devoid of such effect. The sedimentable fraction of tumor extract could also be precipitated by one-third saturation of the extract with sodium sulfate.

Morelli and Vercellone (141 b) observed that plasma in the atypical anemic forms of erythroblastic leukosis produced by the Oberling and Guérin agent was much less active than whole blood. These workers had found (141 a) that addition of ascorbic acid (in 1:200 concentration) to leukotic plasma produced a precipitate and after its removal the treated plasma was more active in producing disease. They (141 b) used this ascorbic acid treatment coupled with absorptions by a modified Willstatter's type C aluminum hydroxide in attempts to purify the leukotic agent. They were able to produce disease with plasma from atypical anemic erythroblastic leukosis that had been subjected to treatment with either ascorbic acid alone or a combination of ascorbic acid and aluminum hydroxide. It was found that after repeated absorptions with aluminum hydroxide had reduced the nitrogen content of the treated plasma to less than 10 percent of the original value, the activity was lost. Attempts to reactivate such inactive plasma by addition of hemoglobin or normal plasma gave variable results which were not considered sufficiently clear to settle the question.

Ruffilli (174 k) reports that the plasma of a chicken which subsequently recovered from leukosis was not infective during the period of the disease. The plasma was, however, capable of producing disease after being reduced by the action of cystein. The whole blood of this chicken produced leukosis without treatment.

Lee and Wilcke (124) have reported that the isoelectric point of the agent in a filtrate of the affected ovary from a bird with "the lymphoid type of fowl leukosis" was between the pH values of 6.01 and 7.01. Although erythroblastic and granuloblastic leukosis occurred in the birds inoculated with this material there were also the other reactions of fowl paralysis and neoplasia in the experimental chickens which, as has been previously discussed, these workers believed due to a common etiologic agent.

Verne, Oberling, and Guérin (207) made tissue cultures of the bone marrow of birds in which leukosis had been induced. One culture of the marrow of a bird infected with the leukosis strain of Engelbreth-Holm was virulent on the 15th day of incubation. Another culture was virulent on the eighth day only, although a mild form of the disease was produced by this culture on the 15th day in one of six chickens which received it. A culture of the marrow of a bird which had been inoculated with the Oberling and Guérin strain of leukosis produced the disease in one of two chickens inoculated on the eighth day. Material of the same culture taken on the 15th day of incubation produced only a mild reaction of the blood in three of six birds inoculated with it. Leukotic blood or marrow kept in sealed tubes at the same temperature as the tissue cultures served as controls and none of the birds receiving this material developed the disease.

Furth and Stubbs (86) reported that tissue cultures of a tumor induced with their Strain 13 agent were capable of producing sarcoma or a combination of sarcoma and erythroblastic leukosis on the 12th, 23rd, 35th, and 67th days of incubation at 39° C. More recently Furth and Breedis (84) have found that the agent of this Strain 13 was active after 158 days in a culture of the sarcoma, whereas in a culture of normal fibroblastic cells the agent died within two weeks. A culture of the tumor produced by Strain 13 (osteochondrosarcoma) produced fibroblast-like cells. When this culture was introduced into chickens after 91 days of cultivation it caused both the tumor and the reaction usually obtained with the Strain 2 agent from which Strain 13 was derived. The cells in liquid cultures of the buffy coat of leukotic blood (the leukosis being produced by the Strain 1 agent) were still able to cause erythroblastic leukosis after 32 days of incubation. Cultures of the marrow of birds affected with Strain 1 yielded only fibroblastic cells which were without ability to produce disease. The agent of Strain 1 likewise perished in cultures of sarcoma cells (Strain 11).

Ruffilli (174 a, 174 b) has reported that the myocardium from a chicken affected with erythroblastic leukosis yielded a culture of fibroblasts which retained the ability to produce leukosis in chickens for 44 passages over a period of 122 days. Ruffilli (174 g) also made serial cultures, in normal plasma with 15 percent embryonic extract, of marrow obtained from a chicken inoculated 38 hours previously with the leukosis agent of Oberling and Guérin. The marrow itself was infective for chickens and on the tenth day of life *in vitro* (third culture passage) the culture produced leukosis in one of two chickens into which it was implanted. Ruffilli (174 h) also reported that a culture of fibroblasts seemed to carry the leukosis agent which had been associated with it during cultivation. His experiment was carried out by using normal plasma and 20 percent embryonal extract as a nutritive fluid. Fragments of heart muscle from a newly hatched chick were planted in the culture media and beside each portion of muscle was placed a bit of the buffy coat of leukotic blood. Fibroblasts only were present in the cultures after the tenth day *in vitro* (fourth transplant passage). On the twenty-second day *in vitro* (ninth transplant passage) three cultures were injected into each of two chickens. Both died with leukosis after 18 and 35 days. The use of cell free leukosis agent instead of buffy coat in the above experiment would have ruled out the possibility of the leukotic cells themselves becoming transformed into the infective fibroblasts.

The reaction of tissue cultures nourished with plasma from chickens with leukosis and from chickens bearing Rous sarcoma was studied by Ruffilli (174 b, 174 e). His results were similar with plasma from chickens with both types of disease. He compared his cultures so nourished with those in which he used plasma from normal chickens and observed stimulation of the migration of some immature elements (fibroblasts, polyblasts, and chondroblasts) and inhibition of the more mature blood cells (especially the polymorphonuclears). He suggests that this is due to specific action of the agents of leukosis and sarcoma as no such action was noted in a culture of mouse spleen supplied with plasma from a mouse affected with leukemia.

Storti and Mezzadra (186) have given a preliminary report on their attempts to cultivate the agent of fowl leukosis in the chorio-allantoic membrane of the chick embryo. They inoculated the fertile eggs which had been incubated for from 4 to 15 days with three to four drops of leukotic material, usually blood. The membranes were removed from the incubator at various time intervals, ground up, and inoculated into the breast muscle of susceptible chickens. Membranes from eggs that had been incubated for from 18 hours to 7 days produced the disease. About 75 percent of the membranes which gave positive results showed changes characterized by thickening, opacity, and cornification of the epithelium, together with edema, hemorrhage, hyperemia, and leukocytic infiltration in the mesenchyme. Infertile eggs were inoculated and incubated as a control measure, but in such eggs the ability to produce disease was lost within 48 hours. Van den Berghe and d'Ursel (206 b) report similar successful cultivation of the leukosis agent on the chorio-allantoic membrane of incubated eggs.

The use of such terms as "destroyed," "perished," "viable," and so forth in the preceding discussion might seem to imply that the substance which induces leukosis in chickens is a living agent, but such a suggestion is not intended. Jármai, Stenszky, and Farkas (105) suggested that the agent is an enzyme-like product of the leukemic cells themselves which is capable of so altering the cells which it affects, that it stimulates the newly affected cells to further production of the agent. Jármai (103) pointed out the marked resistance of the leukosis agent and the agent of transmissible chicken sarcoma to roentgen rays as compared to the destruction of tumor-inducing ability of cells of a chemically induced mouse sarcoma and two transmissible mouse carcinomas after exposure to relatively small doses of the rays. Engelbreth-Holm and Frederiksen (53) report that the fowl leukosis agent, partially inactivated by oxidation, could be reactivated by a reduction system of cystein-cobalt sulfate, which is suggestive of a non-living state. Engelbreth-Holm and Rothe Meyer (58) suggest that the term "endogenous agents" might be used to include the agents of fowl leukosis and transmissible fowl sarcomas which they believe are produced in the cells attacked by the agent and are to be regarded as different from the viruses responsible for the more highly contagious diseases. As evidence for the endogenous production of the agent they cite the experiments of McIntosh (140) in which he induced sarcomas in the chicken with tar and demonstrated the transmission of these tumors with a filter-passing agent.

Specificity

The transmissible agent appears to be only relatively specific for *Gallus domesticus*. Engelbreth-Holm and Rothe Meyer (54) stated that a temporary state of anemia followed the intravenous administration of leukemic blood in three of eight guinea fowls. Although typical erythroblastic leukosis did not develop in the guinea fowls, they believed that this case tended to demonstrate the agent as not being entirely specific for *Gallus domesticus*. They found the pheasant to be refractory to inoculation with the leukosis agent, and cite Poll to the effect that the guinea fowl is more closely related to the domestic chicken than either the pheasant or peacock . Stubbs and Furth (192) found the guinea fowl as well as pigeons to be resistant to infection with their agent and cite Ellermann and Bang as reporting that guinea fowl, doves, and turkeys could not be infected. Stubbs (189) later described the successful transmission of leukosis to a hybrid bird (the offspring of a male pheasant and a bantam hen) in which typical leukosis brought about death in 84 days. The blood from this hybrid bird was capable of infecting chickens but was without effect when injected into pheasant. Wakamatsu (209) reported canaries resistant to infection. Geese, ducks, and turkeys inoculated with his Strain III of leukosis agent remained healthy, according to Olson (155). Schaaf (175) inoculated ducks, geese, pigeons, parrots, and canaries without inducing the disease in them. Five guinea fowl were given repeated intravenous inoculations of leukotic chicken blood with the result that three developed a severe anemia after a period of 4, 5, and 14 weeks, respectively. He does not state whether these experiments were conducted with strains of transmissible leukosis isolated by himself or with those he had received from Jármai and from Engelbreth-Holm. Jármai (99) states that waterfowl, sparrows, rabbits, mice, and guinea pigs could not be infected with the disease. Recently Jármai (101) has reported that his strain of erythroblastic leukosis has developed the ability to produce the disease in turkeys, guinea fowl, and pheasants. The disease as produced in these species of fowl was quite similar to that observed in the domestic chicken. The inoculation of 13 turkeys with leukotic material produced leukosis in 7. Three guinea fowl and two pheasants were inoculated with leukotic material from chickens and all died with leukosis within 24 days. All chickens receiving material from either the guinea fowl or pheasants developed typical leukosis. Of 31 chickens inoculated with material from the leukotic turkeys, only two developed the disease and in both instances it was of a mild form. Successive animal passage of the transmissible agent from these two chickens into other chickens resulted in enhancement of its virulence and the production of more severe leukosis. Jármai believed that the transmissible agent was so modified by its passage through the turkey that its virulence for chickens was decreased. Recovery of the virulence was indicated after several successive passages in the chicken. Jármai (101) also records unsuccessful attempts to infect pigeons with leukosis after the birds had undergone exposure to roentgen rays, damage to the bone marrow, or had been given repeated inoculations. He was unable to produce the disease in ducks, geese, a quail, a sparrow hawk, and a peacock.

Morelli and Vercellone (141 b) report that the leukosis agent of Oberling and Guérin produced a transient leukosis-like reaction in one of five pheasants. Two other pheasants developed a temporary state of anemia. They regard this as an indication of the ability of the leukosis agent to cause disease in pheasants.

Greppin (91), working with Oberling and Guérin's strain of the leukosis agent, reported the production of fatal leukosis in two of three guinea fowl and one of three turkeys inoculated intracerebrally. Two guinea fowl and two turkeys inoculated intravenously remained negative. Pigeons, geese, and ducks were found to be resistant to either mode of inoculation.

The report of Schirrmeister (176), in which he described the transmission to a chicken of a neoplastic-like process found in a turkey, should be accepted with reservations. The reaction in the turkey involved the intestine and mesentery and consisted principally of mononuclear cells. An emulsion prepared from this tissue was injected into the subcutis of a chicken, a guinea pig, and a rabbit. A transient leukocytosis was observed in all animals and in the chicken reappeared at two later intervals, each episode being separated by a period of remission. The chicken died three and a half months after inoculation with "diphtheria" and tuberculosis, at which time a small mass was found at the site of inoculation. The histological appearance of the mass was similar to that of the original material from which the inoculum was prepared. Serial passage of this process and elimination of the possibility that this might represent a granulomatous process would have made more plausible the conclusion of Schirrmeister that this was transmission of leukosis from one species of fowl to another.

The modification of the species specificity of the agent causing transmissible fowl leukosis is indeed interesting. As has been mentioned, the majority of strains of this disease have failed to show any effect in turkeys, guinea fowls, and pheasants. The varied degrees of virulence of the different strains may well account for the difference in the results obtained by various workers in their attempts to infect these kinds of fowl. Neoplastic diseases similar to lymphocytoma of chickens have been noted in many species of fowl (canary, pigeon, duck, goose, and turkey (Richter, 169), but in none of these species has the disease been demonstrated to be transmissible.

Jármai (103 a) has reported the spontaneous occurrence of leukosis and sarcoma in a small parrakeet (*Melopsittacus undulans*). The bird had a small spindle-cell sarcoma in the subcutis of each wing and the blood and organ changes were characteristic of erythroblastic leukosis. Jármai injected emulsions of the organs of this bird and minced tumor fragments into other parrakeets (of similar but not identical type), canaries, chickens, pigeons, and mice without positive results in any species.

IMMUNITY

Fowls resistant to the transmissible agent of leukosis have been encountered in the experiments of all investigators of the disease. This resistance does not appear to be absolute, as chickens which withstand the first inoculation may succumb to subsequent inoculation (Ellermann 37, Rothe Meyer and Engelbreth-Holm 171, and Engelbreth-Holm 48). Greppin (91) noted 10 resistant birds in his work with the leukosis strain of Oberling and Guérin; all succumbed to the disease after the fifth or sixth inoculation. Rothe Meyer, Engelbreth-Holm, and Uhl (174) state that such naturally resistant birds are not uncommon among adult chickens, but that they have never found such resistance in a chick less than two months of age. It has been the general experience that a greater number of resistant birds have been encountered in the first few passages of a new strain of the disease agent and it is possible that the natural resistance of the experimental birds used in the later passages of the agent is overcome by an enhanced virulence acquired by repeated animal passage.

Spontaneously recovered birds seem to possess some degree of resistance to subsequent inoculation with the agent of leukosis (Jármai, Stenszky, and Farkas 105, Furth 76, Rothe Meyer and Engelbreth-Holm 171, and Greppin 91). Ellermann (36) noted that fowls spontaneously recovered from the disease were susceptible to further inoculation. Rothe Meyer, Engelbreth-Holm, and Uhl (174) observed one spontaneously recovered bird to be refractory to nine subsequent inoculations with agent-containing material; however, the tenth inoculation resulted in the development of typical erythroblastic leukosis 25 days after its administration. Furth's experiments (76) indicated that the spontaneously recovered chickens were more likely to become affected if the subsequent inoculation was made with cell-containing material rather than leukotic material free of cells.

Rothe Meyer, Engelbreth-Holm, and Uhl (174) report that the immunity of chickens naturally resistant, or the immunity of birds following spontaneous recovery, protects the birds not only from the strain with which they were inoculated, but also from other strains of the leukosis agent as well (this included their Strain E-S). In this connection it is of interest that Stubbs and Furth (195) found that most chickens which were immune to their Strain 1 were also resistant to Strain 2, but not to Strain 13. Oberling and Guérin (148) inoculated sarcoma material (the sarcoma induced by their strain of leukosis agent) into the breast muscle of 15 chickens which had been refractory to a previous inoculation with the leukosis agent. A small nodule, which later regressed, developed at the site of injection in only one chicken. Eight of these birds were later successfully inoculated with material from an unrelated transmissible chicken tumor similar to the Rous sarcoma.

The blood plasma of spontaneously recovered chickens was demonstrated to have a relative neutralizing effect on the agent contained in leukotic blood plasma, but none on leukemic whole blood (Furth 76, and Rothe Meyer and Engelbreth-Holm 173). Exposure to a temperature of 52° C. for 30 minutes did not destroy the inhibiting action of plasma from a spontaneously recovered chicken (Rothe Meyer and Engelbreth-Holm, 173). The relative nature of such a neutralization effect was indicated by Furth's experiments. He (76) found that 7 out of 27 chickens developed the disease when inoculated with a mixture of leukotic plasma and plasma from birds that had recovered from the disease. In another experiment 6 out of 15 fowls developed leukosis after inoculation with a similar mixture using normal blood plasma instead of that obtained from recovered birds. The exposure of serum and agent was limited to 20 minutes in the above experiments. When this exposure time was lengthened to an hour at 37.5° C. complete protection was obtained in eight birds receiving a mixture of neutralizing serum and cell-free agent. Rothe Meyer, Engelbreth-Holm and Uhl (174) found that the plasma of a chicken with chronic erythroblastic anemia (a chronic form of erythroblastic leukosis) was also capable of neutralizing the cell-free agent. This characteristic was not manifest by the plasma from a case of acute leukosis, (the leukosis agent in the plasma of these diseased birds was destroyed by heating to 55° C. for a half hour). These workers also report that the plasma of a chicken recovered from their pure strain of erythroblastic leukosis would neutralize the agent of their complex strain E-S as well.

Uhl, Engelbreth-Holm, and Rothe Meyer (205) demonstrated a neutralizing action on the agent of leukosis by the serum of ducks which had received multiple injections of leukotic chicken blood. They were able to completely neutralize the agent present in cell-free leukotic plasma with the serum of such ducks and to inhibit the action of the agent in whole leukotic blood. Serum from normal untreated ducks or those which had received injections of normal chicken blood was devoid of this power. The neutralization tests were conducted *in vitro* at a temperature of 37° C. for two hours. Greppin (91) found a slight neutralizing action in the acetone extract of the serum of ducks which had received washed leukosis corpuscles. He also found a slight neutralizing effect with the serum obtained from rabbits treated with bone marrow of a leukotic chicken.

Attempts have been made to convey passive immunity to chickens with serum of a spontaneously recovered chicken, but without success (Jármai, Stenszky, and Farkas 105, Wallbach 213).

The subcutaneous and intramuscular injection of leukotic material into chickens has not produced a significant degree of active immunity (Jármai, Stenszky, and Farkas 105, Engelbreth-Holm 47, and Ellermann 40). Oberling and Guérin

(150) found that the intracutaneous inoculation of leukotic blood was no more effective in inducing a state of immunity than were other modes of inoculation. Jármai, Stenszky, and Farkas (105) attempted to produce an active immunity by injection of organ emulsion of the chick embryo without success. Chickens which did not develop leukosis after receiving an inoculation of the agent-neutralizing plasma mixture succumbed to a later inoculation with leukosis agent alone, indicating that a state of active immunity was not produced (Rothe Meyer, Engelbreth-Holm, and Uhl 174).

Greppin (91) believed that he obtained some immunizing action with the use of leukotic material that had been heated to 56° C. for from 20 to 40 minutes. Wakamatsu (209) reported some experiments with the pure erythroblastic strain of the Danish workers. He administered repeated intravenous doses of bile from diseased birds and obtained, in birds so treated, some degree of protection to subsequent inoculation with the active agent. Oberling and Guérin (143) in unpublished work found that, although bile would inactivate the agent of leukosis, the mixture was without effect as an immunizing agent.

Recently, Uhl (204) reported that he was able to secure some degree of active immunity in chickens against the leukosis agent. His immunizing agent was prepared by grinding the spleens of four chickens, diseased with the E-S strain of agent, with the blood of these same birds. The resultant mixture was subjected to slow centrifugation followed by passage through an ultracentrifuge and then diluted with two volumes of physiological salt solution. At this stage the material was tested by animal inoculation and it was found that its activity was decreased (one preparation produced the disease in only one of six birds into which it was inoculated and another in three of six chickens). The material was then mixed with Type C aluminum hydroxide in 2 percent solution and stored at —5° C. Ten hens and 11 chicks received a series of 12 subcutaneous injections of the immunizing material over a period of two months, and one month after the last immunizing injection all were given a test dose of active leukosis agent. Two of the hens and four of the chicks developed leukosis. The remainder (eight hens and seven chicks) were given three further inoculations with active agent, which produced the disease in four of the hens and four of the chicks. The course of the disease in these birds was somewhat longer than that in control, non-immunized birds receiving a single inoculation of the active agent. The controls consisted of a group of 10 chicks and 20 hens and all of the control group with the exception of one chick died with leukosis. Plasma from seven of the immunized birds was pooled and found to have a neutralizing action on the leukosis agent. Uhl expressed the belief that the agent was bound to the aluminum hydroxide and was liberated so slowly in the animal body that the majority of the birds obtained sufficient stimulation to develop an immunity, but not enough agent was liberated to produce the disease.

Ruffilli (174 i) found that the leukosis agent in plasma was quickly destroyed by bubbles of gaseous oxygen. A group of four animals that had received plasma thus inactivated were given two inoculations of ground leukotic spleen 25 and 45 days after they had received the plasma without developing the disease. A third inoculation with leukotic spleen caused leukosis in two of the chickens, indicating the transient nature of the immunity produced (174 j). In another experiment (174 j) ten chickens remained negative after receiving an injection of the washing from a five-day-old culture of normal bone marrow in leukotic plasma. After 35 days the group was inoculated with leukotic plasma and only two developed leukosis, which he believes indicates some antigenic capacity of the leukotic plasma after being used in the tissue culture. In another publication

(174 c) he reports that leukotic plasma inactivated by other oxidizing agents also has the ability of inducing in chickens a certain degree of immunity against the leukosis agent.

Greppin (91) and Marchal, Paturel, Guérin, and Guérin (134, 135) reported that the serum protein was below the normal level in birds affected with leukosis and was higher than normal in chickens recovered and resistant to further inoculation. Schmitt (178) observed the serum proteins to be slightly decreased in the well-developed disease, although the globulin fraction was relatively increased which he believed to be the result of increased destruction of blood cells.

Marchal, Paturel, Guérin, and Guérin (135) have indicated that the decrease of serum protein in chickens with the active disease was of the albumin fraction and that the increase of serum protein in immune chickens was in the globulin fraction with a normal level of albumin. Chickens with either of two transmissible sarcomas were found to have a decreased quantity of both albumin and globulin in their blood serum (134). These conditions were not constant, as Marchal and his coworkers (135) state that in ten instances animals with a normal or subnormal globulin value were resistant and, conversely, some with high globulin values were susceptible to reinoculation. They concluded that the increase of globulin did not support the immunity but that it was rather a result of the increased resistance.

Thomsen, Engelbreth-Holm, and Rothe Meyer (200) found complement-fixing antibodies in the serum of about 20 percent of leukotic chickens. The antigen used in the tests was a watery extract of either erythroblasts or myeloblasts from leukotic chickens. The antibodies were those directed against antigen foreign to the inoculated chickens and contained in the blood cells or material used to induce the disease rather than against the leukosis agent. Greppin (91) carried out a small number of complement-fixation tests using as antigen either an alcoholic extract of dried leukotic liver or an alcoholic extract of a leukotic liver previously washed with acetone. The serums of four normal chickens were negative as were those of 12 of 13 leukotic birds.

Kabat and Furth (118 a) have reported on the use of crude tumor extracts, leukotic plasma, and high-speed centrifugates, all containing the agent of either Strain 1 or Strain 13 and supernatant fluid from the centrifugates as antigen. Complement-fixation tests using serums of chickens with chronic sarcomas produced by Strain 13 agent or from those resistant to repeated inoculation with the agents of Strain 1 or 13 or high-speed centrifugate were uniformly negative. Rabbit-antiserums against crude tumor extract, high-speed centrifugate and supernatant fluid of sarcoma produced by Strain 13 agent, buffy coat of normal chicken blood, and centrifugate of normal chicken spleen gave strong complement-fixation reactions and cross reactions which indicated no antigenic difference between the materials. Absorption tests with the complement-fixation reaction and precipitin tests indicated that the bulk of material sedimented by high-speed centrifugation from leukotic, sarcomatous, and normal tissues are of a similar antigenic composition.

Olson (155) attempted to demonstrate tissue sensitivity in ducks, geese, turkeys, and chickens inoculated with material containing the agent of fowl leukosis. The test materials, that is, leukotic bone marrow extract and a filtrate of leukotic bone marrow, failed to elicit specific reactions when injected intradermally.

TREATMENT

The majority of attempts to find a therapeutic substance for the treatment of fowl leukosis have given discouraging results.

Jármai (99) reported that irradiation with roentgen rays in the early stages of the disease would occasionally cause a decrease in the number of leukemic cells in the blood and prevent the development of splenomegaly but, when the irradiation was stopped, the disease progressed to a fatal termination. Thorium, in doses of 200 electrostatic units, prevented the increase of leukemic cells in the blood in some instances and apparently in some instances brought about complete recovery. The spleen remained small in birds that received thorium. The administration of atoxyl or benzol to chickens ill with leukosis was found to be without benefit.

Zadik (220) claimed beneficial effects in the treatment of leukosis with an organic lead preparation "R237b" (Rothmann), a sodium plumbo-dithio-pyridin-carbonate. Oberling and Guérin (152) reported a definite inhibitory effect of quinine and some of its derivatives (plasmochine and rhodoquine) in some cases of leukosis. Engelbreth-Holm, Rothe Meyer, and Uhl (60) repeated these experiments and found that neither the lead preparation nor the plasmochine had any beneficial effect on the disease produced by either Strain R or Strain E-S. Rhodoquine had no effect on animals inoculated with Strain E-S but did tend to prolong the course of the disease and to lower the percentage of successful inoculations of the Strain R agent in chickens. It also showed some ability to inactivate the agent of Strain R *in vitro*.

Kitt (121) states that arsenic, in the form of Fowler's solution, and potassium iodide were of no value in the cure of the disease. Olson (155) found that treatment of leukotic birds by feeding liver or by transfusion of whole blood from either normal chickens or birds recovered from the disease had no lasting effect on the disease. Arsenic was likewise found to be of no benefit in the treatment of affected chickens.

Schaaf (175), in his work on experimentally produced fowl leukosis, was unable to demonstrate any therapeutic effect of lead, arsenic, iron, or copper compounds, R237b (Rothmann's lead preparation), plasmochine, liver or liver extracts, or certain hormone preparations.

Wheat germ oil has been recommended as a supplement to the diet of chickens to reduce the incidence of a group of diseases classified as "leukosis" (Butler, Warren, and Hammersland 21) and had previously been suggested for the treatment of the disease (20). Several individuals have investigated this claim and found wheat germ oil to be without effect either as a cure or as a preventive agent for fowl paralysis or "lymphomatosis" (5, 24, 116, 196).

ATTEMPTS TO PRODUCE LEUKOSIS WITHOUT THE USE OF THE SPECIFIC AGENT

Kasarinoff (120) was one of the first to report the production of a leukemoid blood picture in chickens by the administration of chemical substances. He observed a leukocytosis as result of nucleic acid treatment, a promyelocytosis following nucleohiston, a myeloblastosis after ricin and saponin, a lymphocytosis caused by cantharidin, and an eosinophilia brought about by ricin and guanin. He did not describe the organ changes or attempt to transmit the conditions which he produced.

Gohs (90) believed that leukosis was caused by decomposition products of the bone marrow cells, for the proof of which he irradiated the marrow from chick embryos or glycerinated marrow of adult chickens which was then injected into the experimental chickens. Osteitis fibrosa, erythremia, anemia, and myeloid leukemia were observed in these chickens. These conditions was transmitted for two serial passages. No instances which could be interpreted as erythroblastic leukosis were found among these chickens and the myeloid reaction might well be looked upon as leukemoid in character.

Furth (72) and Jármai and Balo (104) both report attempts to produce a condition of erythroleukosis by removal of large quantities of blood, but they found that the appearance of polychrome erythrocytes in the circulation was only transient. Wirth and Kubasta (217) noted that the anemic condition of the blood of chickens after removal of approximately half the blood volume quickly returned to normal (within eight days following one blood letting and nine to fifteen days following a second removal of blood). Pyrodine (acetylphenylhydrazine) was found effective in producing an erythroblastic hyperplasia of the bone marrow, but the blood picture of the birds thus treated was that of a regenerative anemia (Furth, 72). There was no tendency of the immature cells in the blood to undergo stasis in the organs of these chickens, a characteristic of the pathology in leukosis as produced by the agent of transmissible fowl leukosis. Ricin, saponin, and toluylene diamine were studied in a similar manner by Furth (72). He found that they did not produce a condition of erythroblastic leukosis.

Thomsen and Engelbreth-Holm (198, 199) injected a carcinogenic tar into the tibial bone marrow of chickens at five-day intervals. There were 62 chickens in the experimental group that received tar injections and some also received irradiation with roentgen rays. After one to four and a half months of treatment nine birds developed a condition similar to spontaneous "myeloid leukosis" and two erythroleukosis. The livers and spleens of the nine animals were enlarged, with foci of myeloid metaplasia consisting principally of myelocytes and in some there was a marked increase in the number of circulating leukocytes, principally of the granulocytic series. One of the two cases of erythroleukosis was of the anemic variety. The blood picture of both types of reaction was not as severe as was usually noted by these workers in spontaneous cases of leukosis. Their attempts to transmit the condition produced by the tar injection to other experimental chickens by the methods usually employed for transmission of leukosis gave only inconclusive results. Nine chickens were given repeated doses of the tar emulsion intravenously, but the injections were without effect.[3]

Jármai and Balo (104) report that subcutaneous injection of a tar-benzol mixture every ten days for seven months resulted in the development of a leukosis-like condition in four of nineteen chickens thus treated. The leukocyte count of the blood was increased (75,000 to 95,000 cells per cu. mm.) and myeloblasts, myelocytes, and large cells similar to an endothelial cell appeared in the blood. The spleens and livers of these animals were enlarged and contained foci of myeloid metaplasia. Tests for transmission resulted in the development of a transient myeloid reaction without causing death of the experimental animals.

Oberling, Sannie, Guérin, and Guérin (153) report the production in chickens of a non-transmissible condition similar to leukosis by injection of either colloidal benzpyrene solution or benzolbenzpyrene solution. The occurrence of two cases of transmissible erythroblastic leukosis in a group of ten chickens receiving biweekly injections of benzpyrene was reported by Jármai and Balo (104). A series of 16 passages of the transmissible agent from one of these cases was made and the agent was found to remain active in glycerin solution. These results were not reproducible and Jármai and Balo, therefore, were inclined to believe that the two instances of disease in the treated chickens were spontaneous. Methylcholanthrene was found by them to give negative results when injected in the chicken. They also administered a 0.25 percent solution of maretin (an antipyretic drug which has been known to produce an anemia and leukocytosis) in 0.1 cc. doses at weekly intervals. An increase of erythrocytes and leukocytes began about the eighth to tenth day after injection of maretin. The majority of the leukocytes were myeloblasts and poikilonuclear cells (leukoblasts). After a second injection an anemia began to develop although the leukocytes continued to increase. The chickens lived from two to three months during which time they became emaciated and more anemic. The organs showed only a very mild reaction, not like typical leukosis. Attempts were made to transmit the disease from two of the chickens which had received the maretin solution with the result that the condition was carried through two passages in each instance, but could be carried no further.

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[3] An experiment was conducted by Bernard (13) in which he brought about a myeloid disturbance by the injection of tar into the marrow cavity of white rats. An erythrocytosis and erythroblastosis were produced and about half of the animals showed changes of the leukocytes. He was unable to transmit the condition to other rats.

Yudina (219) observed leukemoid reactions in chickens injected subcutaneously with a ½ percent solution of 1:2:5:6 dibenzanthracene in chicken fat. These injections were administered in 0.1 to 0.2 cc. doses every six days for five months, and the birds were observed for a total of eight months. Among 42 chickens thus treated she observed one case of "leucaemia" (granuloblastic leukosis?), three cases of "aleucaemic myelosis" (myelocytoma?) one of which was associated with development of sarcoma at the site of injection, three cases of "erythroblastosis" (erythroblastic leukosis?), and one case of local sarcoma development without leukosis. Unfortunately, there is no mention of attempts made to transmit the experimentally produced conditions.

Thomsen, Engelbreth-Holm, and Rothe Meyer (201) report an unusual circumstance in which erythroblastic leukosis occurred in a number of chickens which received whole blood mixtures from other birds not affected with leukosis. They were unable to give an explanation of this development which happened in the course of certain unrelated immunological studies.

Winternitz and Schmeisser (216) observed the occurrence of leukosis in the course of some experimental work with *Salmonella gallinarum*. They suggested the possibility of reproducing leukosis by properly regulated doses of the fowl typhoid bacillus.

Emmel (46) in an extensive series of publications (for references see his paper cited) has discussed the results of his work indicating that fowl leukosis among other diseases can be produced by the action of members of the *Salmonella* genus of bacteria. Recently he has expressed the belief that atmospheric conditions, such as decrease of oxygen and increase of carbon dioxide, may be a factor contributing to the induction of leukosis. The fact that Olson and Goetchius (158) and Beach and Twisselmann (10) were unable to confirm Emmel's findings (the production of these diseases by members of the *Salmonella* genus) tends to invalidate this portion of his work. The condition of hemocytoblastosis so frequently mentioned by Emmel in his publications is difficult to visualize and comprehend from his descriptions. Recently, Blount (16) has reviewed the subject of so-called hemocytoblastosis of the chicken and suggests that the term has been used by Emmel in a broad sense to indicate a number of alterations, some physiological and others of minor pathological significance, which represent a type of myeloid response and are not in themselves to be considered as a specific disease.

CONCLUSIONS

Transmissible fowl leukosis is a usually fatal, specific disease which occurs naturally in the chicken. It is caused by a filter-passing agent whose ability to produce disease is enhanced by successive animal passage. The different strains of fowl leukosis agent vary in their action. Some cause stimulation of erythroblastic cells only; some have the ability to stimulate the granuloblastic cells; others under certain conditions are capable of producing sarcoma. The existence of agents capable of inducing fowl paralysis and lymphoid tumors as well as leukosis is an unsettled question. Fowl leukosis is not highly if at all contagious and the possibility that the disease agent is of spontaneous origin in the affected animal must be seriously considered. The disease is readily transmitted when the pathogenicity of the particular strain of agent in question has become established. The bile, urine, and feces of affected birds are either devoid of the agent or contain it in an inactive form. The agent can be demonstrated in most of the tissues of diseased chickens by inoculation of the material into other birds. Strong doses of roentgen rays do not destroy the activity of the agent. The agent is relatively resistant to drying, freezing, and to glycerin solutions. It is thermolabile and susceptible to inactivation by oxidation. Many chickens have a natural relative resistance to the agent. Some few recover from the disease and gain a variable degree of resistance thereby. The serum of such recovered birds is capable of neutralizing the action of the agent *in vitro*, as is also the serum of ducks which have been subjected to a series of injections of the agent. Some strains of the agent have produced the disease experimentally in pheasants, guinea fowl, and turkeys, although other species of fowl are resistant to their action. No practical therapeutic agents have yet been found for this disease.

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SYNOPSIS OF THE VARIOUS TRANSMISSIBLE STRAINS OF FOWL LEUKOSIS AGENT

Author and Reference	Year Described	Designation of Strain	Number of Serial Passages	Type of Disease Produced
Ellermann and Bang (45)	1908	A	6	Leukosis
		B	1	Leukosis
		C	2	Leukosis
Schmeisser (177)	1915	–*	5	Leukosis
Magnusson (133)	1915	–	1	Leukosis
Ellermann (42)	1921	D	2	Leukosis
		E	6	Leukosis
		F	1	Leukosis
		G	1	Leukosis
Ellermann (40)	1921	H	12	Leukosis
Stazzi (181)	1927	–	?**	Leukosis
Andersen and Bang (2)	1928	–	?	Leukosis
Battaglia and Leinati (6)	1929	–	1	Leukosis
		–	2	Leukosis
Furth (69)	1929	1	Numerous	Leukosis
Jármai (97)	1930	–	Numerous	Leukosis (erythroblastic) and sarcoma
Engelbreth-Holm (47)	1931	R	Numerous	Leukosis (erythroblastic) and sarcoma
Engelbreth-Holm and Rothe Meyer (55)	1932	T	Numerous	Leukosis (erythroblastic)
		T_1	16	Leukosis (granuloblastic)
Jármai, Stenszky and Farkas (105)	1932	–	5	Leukosis
		–	?	Leukosis
Patterson, Wilcke, Murray, and and Henderson (163)	1932	–	?	Leukosis, lymphomatosis and fowl paralysis
Olson (154)	1932	I	3	Leukosis
		II	4	Leukosis
Furth (77)	1933	2	Numerous	Lymphomatosis, myelocytomatosis, endothelioma
Rothe Meyer and Engelbreth-Holm (171)	1933	E-S	Numerous	Leukosis and sarcoma
Oberling and Guérin (144)	1933	–	Numerous	Leukosis and sarcoma
Johnson (108)	1934	–	3	Leukosis, hemocytoblastosis, fowl paralysis
Nyfeldt (142)	1934	–	Several	Leukosis (granuloblastic)
Engelbreth-Holm and Rothe Meyer (58)	1935	Ø	14	Leukosis (erythroblastic)
		AA	3	Leukosis (erythroblastic) and anemia
Stubbs and Furth (195)	1935	13	Numerous	Leukosis and sarcoma
Furth (81)	1936	12	Numerous	Lymphomatosis and osteochondrosarcoma
Schaaf (175)	1936	–	?	Leukosis
		–	?	Leukosis
		–	?	Leukosis
Olson (155)	1936	III	20	Leukosis
Lee, Wilcke, Murray, and Henderson (125)	1937	–	?	Leukosis, lymphomatosis, fowl paralysis
Pikowski and Doljanski (165)	1938	–	7	Leukosis, sarcoma, reticulo-endotheliosis
Fitch (65)	1938	–	1	Leukosis
Hamilton and Sawyer (92)	1939	–	12	Leukosis (erythroblastic)

*No specific designation given. **Number of serial passages not indicated.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 371 June, 1940

Cranberry Growing in Massachusetts

By Henry J. Franklin

Massachusetts produces more than one half of all the cranberries grown in the world. It is, therefore, considered desirable to issue a bulletin dealing with the cultural practices of this important crop.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

CRANBERRY GROWING IN MASSACHUSETTS

By Henry J. Franklin,

Research Professor in Charge of the Cranberry Station

The cranberry of commerce[1] is native to North America only, although a closely related species[2] grows in northern Europe and Asia. That species, however, has such small berries that it is not suitable for cultivation. Our American cranberry is grown a little in Holland and England but extensively only in North America. The fruit is used mainly in the United States and Canada, no large foreign market having been developed.

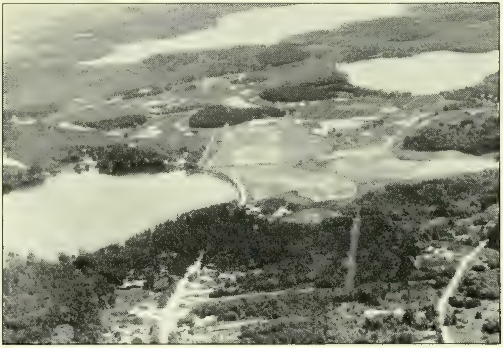

Fig. 1. Cranberry Bogs from the Air.

The bogs in the foreground look whiter than those in the background because they were partly flooded.

Commercial cultivation of the cranberry began on Cape Cod and in Middlesex County a hundred years ago. It paid well from the start and has developed so that this fruit is now the leading export crop of the State, bringing in a gross annual return of from $3,000,000 to $5,000,000. The industry here, except for a few small bogs, is confined to Middlesex, Bristol, Plymouth, Barnstable, Dukes, and Nantucket counties, the Plymouth County crop being more important than the others, with Carver, Plymouth, and Wareham the most productive townships. Cranberries are also grown in New Jersey, in Wisconsin, on the coast of Oregon and Washington, in Nova Scotia, and on Long Island, these districts being named in the order of their importance in the industry.

In Massachusetts, 13,644 acres were under cranberry cultivation in

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[1] *Vaccinium macrocarpon* Ait.

[2] The "moss" or "speckled" cranberry (*V. Oxycoccus* L.)

1934.[3] A New Jersey cranberry survey[4] in 1932 gave a total of 11,944 acres. Wisconsin has about two-thirds of the rest of the acreage of the country, there being 2120 acres cultivated there in 1928[5] and about 300 acres more which have come to bearing since then, with nearly 300 acres of new planting yet to bear in addition (Vernon Goldsworthy). These figures, however, fail to show how much land is devoted to the industry, for they leave out the sand banks and other upland around the bogs and the land used for reservoirs. With all this included, the total area used for this crop may exceed 70,000 acres.

Production of Cranberries (Barrels).

Year	Massachusetts	New Jersey	Wisconsin	United States Total
1901	264,000	105,000	40,000	409,000
1902	238,000	30,000	46,000	314,000
1903	226,000	168,000	18,000	412,000
1904	281,000	83,000	21,000	385,000
1905	165,000	88,000	18,000	271,000
1906	264,000	103,000	45,000	412,000
1907	310,000	121,000	21,000	452,000
1908	257,000	75,000	12,000	344,000
1909	402,000	165,000	30,000	597,000
1910	312,000	241,000	16,000	569,000
1911	298,000	143,000	30,000	471,000
1912	354,000	112,000	45,000	511,000
1913	367,000	100,700	30,000	497,700
1914	471,000	210,000	32,000	713,000
1915	257,000	184,000	36,000	477,000
1916	364,000	217,000	33,000	614,000
1917	137,000	129,000	30,000	296,000
1918	218,000	126,100	29,900	374,000
1919	395,000	143,000	46,000	584,000
1920	309,000	133,000	36,000	478,000
1921	208,000	160,000	29,000	397,000
1922	337,000	200,000	55,000	592,000
1923	451,000	205,000	37,000	693,000
1924	339,000	215,000	42,000	610,000
1925	447,000	115,000	25,000	609,000
1926	438,000	210,000	80,000	751,600
1927	385,000	75,000	24,000	511,000
1928	348,000	138,000	50,000	564,000
1929	421,000	90,000	42,000	569,800
1930	395,000	144,000	40,000	585,480
1931	460,000	142,000	45,000	661,000
1932	415,000	80,000	80,000	584,836
1933	506,000	142,000	47,000	703,700
1934	290,000	70,000	59,000	443,300
1935	332,000	85,000	81,000	519,500
1936	346,000	75,000	62,000	504,300
1937	565,000	175,000	115,000	877,300
1938	325,000	62,000	64,000	475,700
1939	490,000	88,000	108,000	704,100

Yields

The average annual acre yield of cranberries in this State ranges from 21 to 41 barrels, but well-managed bogs with proper facilities probably average over 50 barrels in a series of years. The average acre yield is somewhat larger in Wisconsin than in Massachusetts, but elsewhere it is less. The differences are due partly to differing natural conditions for the industry and partly to methods of culture. All of the cranberry bogs in Massachusetts and most of those in Wisconsin are covered with sand. Less than a sixth of the New Jersey acreage is sanded. Most bogs in Massachusetts are kept free from weeds, while most of those elsewhere are very weedy.

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[3] Bulletin No. 332, Mass. Agr. Expt. Sta., 1936.

[4] Circular No. 232, State of New Jersey Department of Agriculture, 1933.

[5] Bulletin No. 96, Wisconsin Department of Agriculture, 1929.

The table giving the cranberry production in the three chief growing regions since 1900 shows the lead this State has in the industry. Our natural conditions for this crop are so good that this lead will be held a long time. The relative lack of suitable and accessible sand is a handicap elsewhere. The New Jersey climate is rather unfavorable, promoting weed and fungous troubles more than those of other cranberry districts. Wisconsin is well placed in the industry and may be a long-term rival in spite of its troubles with drouth and summer frosts; its geographical

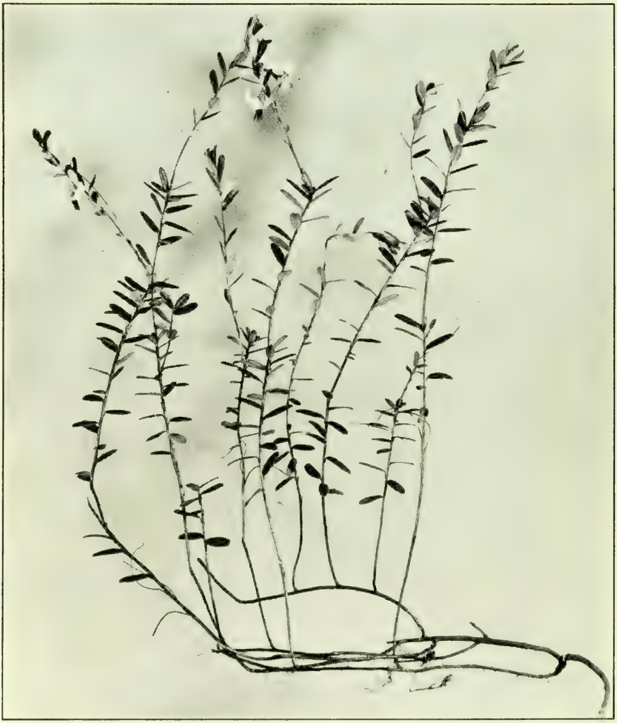

Fig. 2. Part of a Cranberry Vine with Upright Branches.

location gives it an average freight advantage in the delivery of fruit to the markets of the country as a whole; its Searls variety[6], partly because of the large berries, is more productive than any other cranberry variety largely grown; the crop there is harvested more completely and with less injury to the vines than elsewhere by water-scooping[7]. The lack of acidity in many of the marshes in parts of Wisconsin is probably a limiting factor there. (N. E. Stevens).

Cranberries are a luxury but are in such general use that they tend to be a necessity. The market for them has kept pace with their production, and prices for good fruit are usually satisfactory. The average season price per barrel has ranged from $6.30 to $13.40 in the last several years. Some growers fear the supply of cranberries may sometime exceed the demand. This may come to pass temporarily, but important new uses are being found for this fruit and the market for it is being largely extended and stabilized by canning. Moreover, the effective producing cranberry acreage of the country is less now than it was twenty-five years ago. Good cranberry bogs will, therefore, be attractive investments for some time to come. Though the cranberry acreage of this State is somewhat less than formerly, its production has very noticeably increased, probably largely because of reduction of losses by insects and frosts.

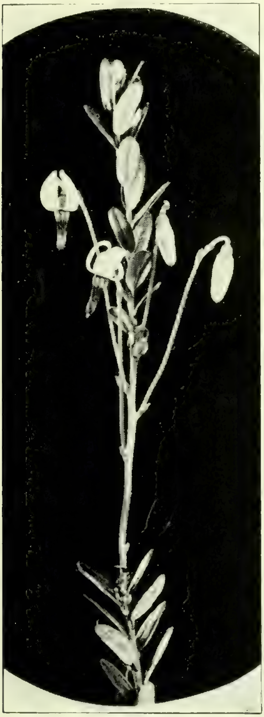

Fig. 3.
Cranberry Flower Buds and Flowers.

THE CRANBERRY PLANT

The cranberry plant is a trailing vine with many upright branches and roots along it (Fig. 2). Both the runners and the uprights have leaves, but only the latter bear fruit. The leaves are evergreen but turn brownish in winter. The vines make a mat all over the surface of a cultivated bog (Fig. 31 B). They blossom in late June and early July, and the fruit ripens in September and October. The flowers (Fig. 3) depend mostly on insects for pollination, but wild bees are so plentiful that it probably seldom pays to keep bees for this purpose. The set of fruit is not affected by night coolness short of frost during the bloom.

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[6] Searls, also called Searls Jumbo, is the main Wisconsin variety (p. 27).

[7] Most of the Wisconsin crop is gathered from the water of the partly flooded bogs with long-handled scoops.

THE ESSENTIALS AND PREPARATION OF AN IDEAL CRANBERRY BOG

Land

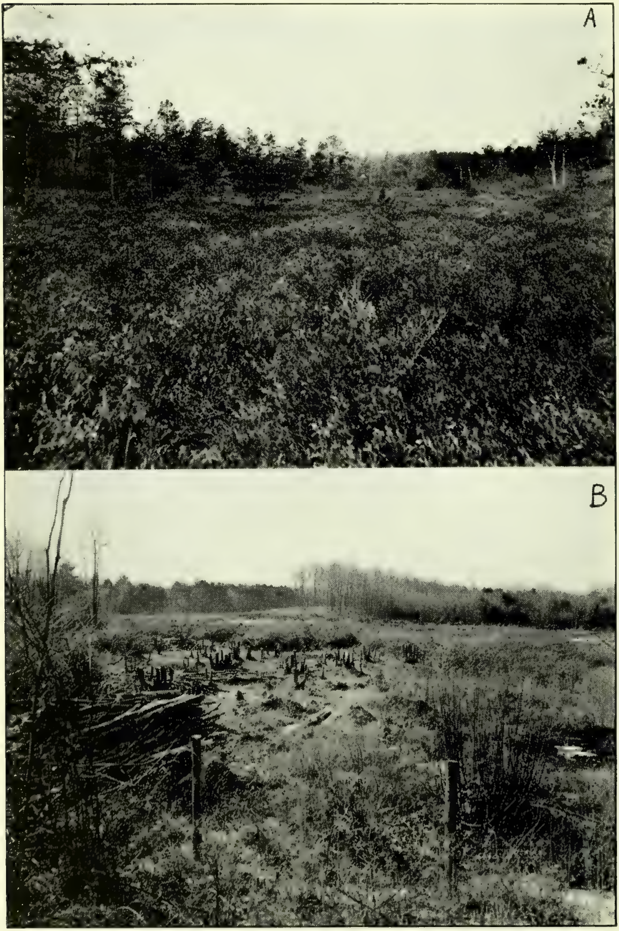

Fig. 4

A. A Leather Leaf or "Brown-Brush" Swamp, excellent land for cranberries.

B. Maple Swamp being cleared and prepared for growing cranberries, with stumps cut high for easy pulling.

Cranberries in cultivation, as in the wild, do best on swamp land of muck or peat. The depth of this soil need not be great, a few inches of peat or one layer of turf over sand or clay often giving good results. It does not appear that any peat is essential, for vines grown on sand alone—so-called "hard bottom"—often produce fair crops when fertilized. The soil must be acid. The plants found growing most commonly on good cranberry soil are: sphagnum moss, wild cranberry, leather leaf ("brown brush") (*Chamaedaphne calyculata* Moench.), sheep laurel (*Kalmia angustifolia* L.), red maple (*Acer rubrum* L.), and cedar (*Chamaecyparis thyoides* BSP.).

Fresh meadow and freshened salt marsh sometimes are made into cranberry bog without turfing, the grass being laid down and covered with about five inches of sand and the vines set out without other preparation except grading and ditching. Swales and pond bottoms may be used. Such bogs are built cheaply and usually do well. Brush swamps (Fig. 4A) are preferable to wooded ones, for it costs less to clear them. If timbered land is used, the tree stumps must be cut at the roots, pulled or dug out (Fig. 4B), and taken from the bog. A winch and hoist is best for this. Dynamite is often used to blow out stubborn stumps, but the filling of the holes made in soft land is costly. Much labor may have been wasted on removing stumps, for on old bogs the vines are commonly more thrifty and productive over buried stumps than on areas between them. It may be best, therefore, to cut down the tops of stumps which are hard to remove and cover them over.

Location

A cranberry bog should be on or near a stream large enough to flood it at any time. If the stream is too small, its capacity for flooding must be increased by making a reservoir above the bog location.

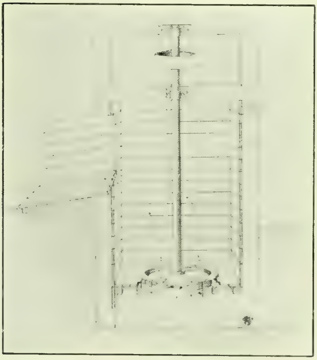

Fig. 5. A Common Bog Pump Installation.

A water supply for flooding as much as may be necessary at any time, especially for flooding by gravity, adds greatly to the value of a cranberry property. It is often difficult and costly to arrange for such a water supply in developing a new bog. In this State there are special laws favorable to cranberry growers in this connection. The water of state ponds is often used, under the direction of the Department of Public Works.

Many fine bogs are flooded by pumping from streams or ponds at lower levels, a third of the acreage in this State being treated in this way. The service of reservoirs is often greatly extended by pumping the water used in flooding back into them again and again. Electric motors or automobile engines are used in most bog pumping plants. The latter are generally preferable, for they are much cheaper to install and operate, are more easily repaired, and are as reliable. Several makes of propeller and reversed-turbine pumps are used (Fig. 5), and they vary greatly in efficiency. Repair service is an important item to be considered as well as efficiency. The pumping plants in use range in lift from 1 to 24 feet, averaging nearly 6 feet. Their horse power averages about 30 and their capacity probably about 6000 gallons a minute. A pump delivering 10,000 gallons a minute will flood 14 acres in 10 hours if the bog is not over a foot out of level.

Stop-waters in bog ditches often help greatly in efficient use of limited water supplies in frost flooding.

The bog should not be shut in by high uplands and woods, for open locations are less frosty, and the berries are more likely to set heavily and ripen early if fully exposed to sunshine.

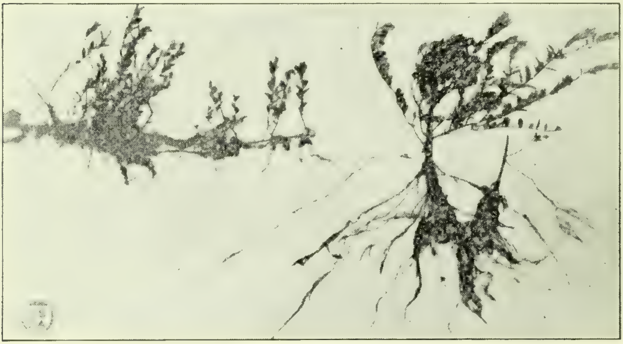

Fig. 6. Cranberry Root Systems.
The plant to the left came from poorly drained, that to the right from well-drained land.

The Form and Size of the Bog

Other things being equal, small bogs pay better than large ones. Long narrow bogs, after a certain size is reached, are more profitable than compact ones. The care of large compact bogs and the harvesting of their crops are disproportionately costly, because it takes more time to wheel sand to the center of the bog and to bring the berries from the center; also, most of the bog operations call for more tramping over, and consequent injury to, the vines on large blocky areas. Another factor limiting the success of large bogs is the greater prevalence of the black-headed fireworm on them. Flooding favors this insect by destroying a fungus that often attacks it severely and by killing or driving from the bog most of its enemies, such as spiders and parasites, at the same time protecting its eggs from the adversities of winter. The natural foes of the pest take longer to reach the center of a large compact bog again in effective numbers than to reach the center of a small one. If, however, a large bog is long and narrow, none of the factors mentioned are unfavorable.

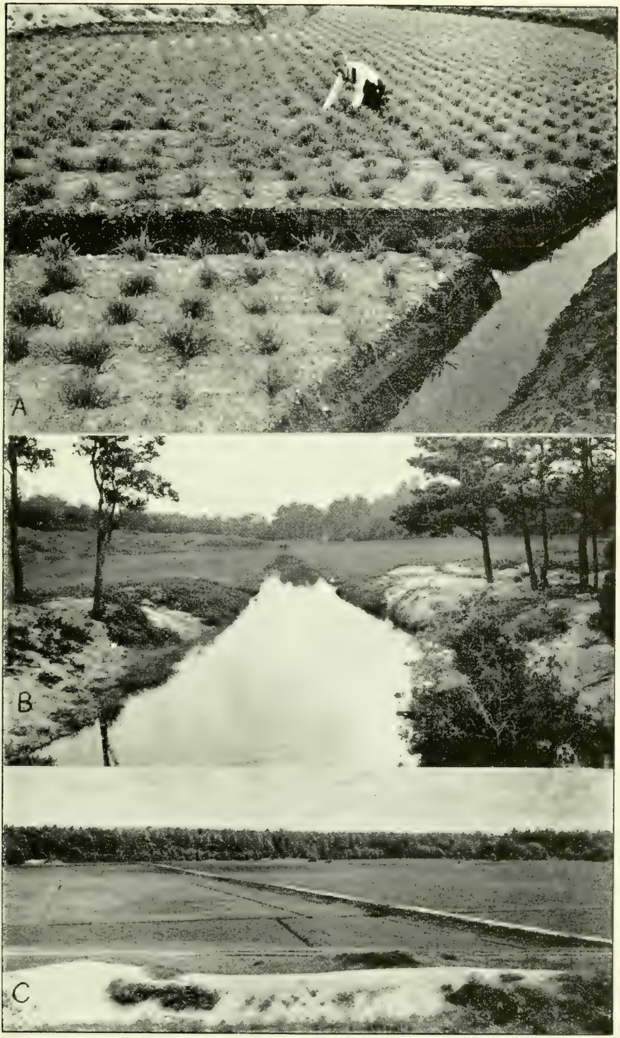

Fig. 7.

A. A Cranberry Bog in the Second Year from Planting, showing the marginal ditch and a cross ditch.

B. Bog with a Good Main Ditch for handling flowages quickly.

C. A Bog Divided with Dams into three Separate Flooding Areas.

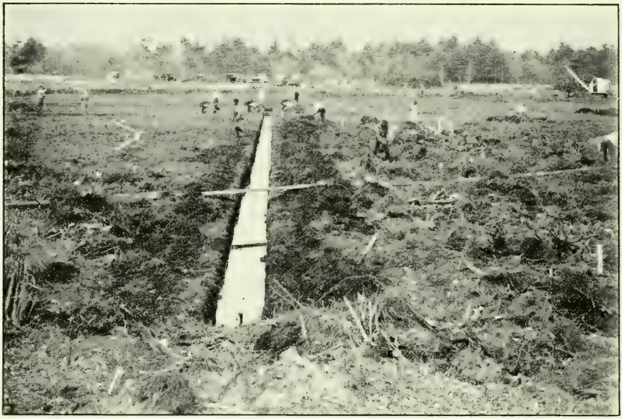

Fig. 8. Bog Construction.

Drainage

A bog should be well drained during the growing season. Poor drainage favors weed growth and the rose-bloom disease and probably promotes infestations of the black-headed fireworm and diseases which cause berries to rot both on the bog and in storage. It also curtails the growth of cranberry roots (Fig. 6). The land below the bog should go down rapidly, so that the water may be drawn from the ditches quickly at any time.

A ditch should be cut entirely around the bog and other ditches dug across it (Figs. 7A and C and 35B), dividing it into sections. The marginal ditch prevents upland growths from working onto the bog, keeps many crawling insects off, and is some protection from forest fires. It should be 3 feet wide and 2 feet deep.

If the drainage from the bog is good, the cross ditches are not important unless the area is great or the bottom close or springy. They hasten the distribution of water over the entire area in frost flooding and irrigating. Without them, the water tends to pile up for a time at the end of the bog where it is admitted. They usually should be 100 feet or more apart, and are made about 2 feet wide at the top, 1 foot wide at the bottom, and 18 inches deep. One of them (Fig. 7B) should be wider than the others and run lengthwise of the bog, in the path of the direct flow from the water supply to the outlet, to hasten flooding and draining. No more ditches should be made than are necessary because they interfere with bog operations. Tile drains are useful if the bog is hard to drain.

Grading

The soil thrown out in ditching may be used in grading. The grading is done by the water line in the ditches. All bogs should be made level, so they may be flooded quickly and with little water, and no swamp that cannot be so graded with moderate expense should be used unless the water supply is very ample. If the swamp is large and much out of level, it is often best to divide it with dams into separate areas (Fig. 7C), each nearly level, at different elevations according to the lay of the land. This greatly reduces the water required for flooding.

It should be remembered in building a bog that the deeper any cranberry flood is, the more it harms the vines.

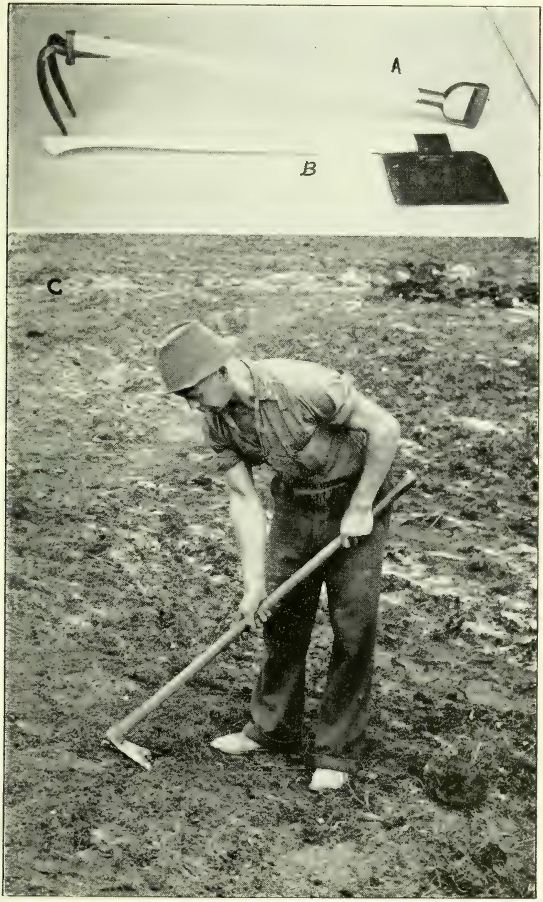

Fig. 9. Tools Used in Preparing a Bog.
A, Turf hook; B, Turf axe; C, Grading hoe.

Preparation of Land

After the land has been cleared of trees and brush and ditched and drained, it is "turfed" or "scalped" (Fig. 8). The turf is cut in squares of handy size with turf axes (Fig. 9B) and these are turned upside down with turf hooks (Fig. 9A) and allowed to dry. They are then broken up easily with a grading hoe (Fig. 9C) and all pieces of roots found in them are burned. Care must be taken at this time to remove from the soil the roots of ferns and of all plants likely to give trouble later as woody weeds, such as horse brier, poison ivy, leather leaf, hardhack, sheep laurel, and chokeberry.

All work on the land up to sanding should be completed late in the summer or in the fall.

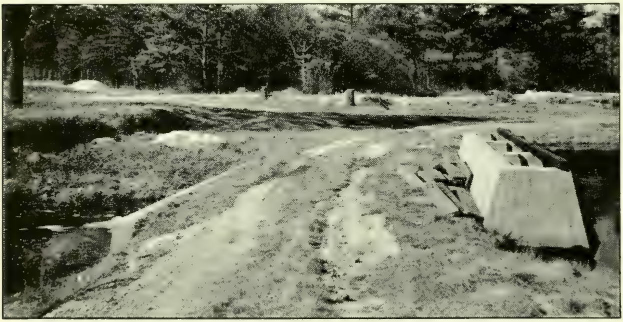

Fig. 10. A Covered or Trunk Gate.

Dams[8]

The reservoir and bog dams (Fig. 7C) usually have a wide core of sand walled on both sides with turf. Sometimes the turf is necessary on only one side. The turf walls are built layer on layer with some sand between the layers for ballast, the pieces of adjoining layers overlapping. The turf is often taken from the upland near the bog; but when the swamp itself is scalped, the turf obtained may be used partly in facing the dams.

A trench deep enough to reach below all tree roots should be dug along the middle of the dam location and filled with sand to make a good connection with the soil for holding water. If the dam is to cross very soft land, it must be sheet-piled lengthwise in the middle with matched boards or planks. It should have sloping sides and be widest at the bottom, with dimensions according to the head of water. The wider it is the better it will resist muskrats. It should be a foot higher than high water to keep waves from wearing a hole through the top. It may also serve as a roadway. It is well to ditch the bog a few feet from the dam, making a berm.

A gate[9] for the passage of the water must be built in the dam—a job which requires an experienced gate builder, for it must be made properly and carefully. It often pays to make the gate of reinforced concrete, but redwood or kyanized cedar lumber is better on soft land. A continuous cross sheet of matched piling under the middle of the gate and extending out into the dam on each side of it is necessary, and two or three sheets may be needed if the water held is to be deep and the soil under the gate is soft or disturbed by springs. A stream of water from the hose of a power sprayer, delivered under high pressure through a piece of iron pipe

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[8] Commonly called "dikes" by the growers.

[9] Commonly called a "flume" by the growers.

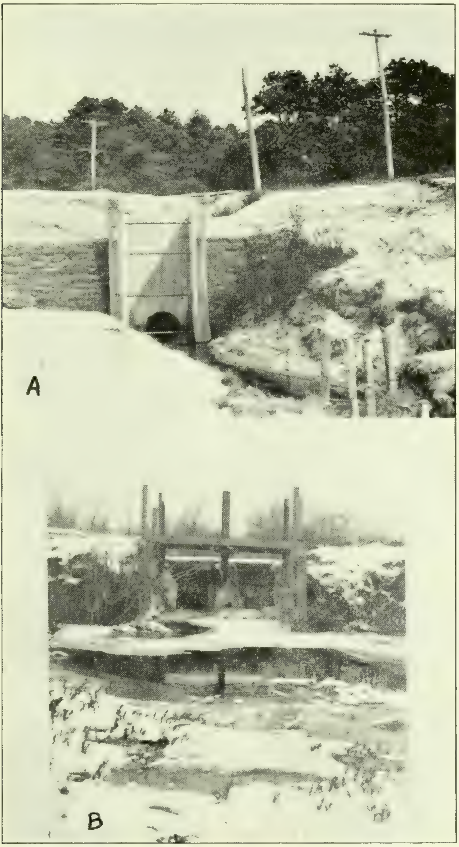

Fig. 11.

A. A Bulkhead and Sewer Pipe Water Gate.

B. An Open Gate. The upright timbers extend well above the top of the dam to permit building the dam higher if this is found desirable.

with its tip compressed to a very narrow slit, helps greatly in driving the piling by loosening the soil.

The most experienced growers prefer the covered or trunk gate (Fig. 10). It is much stronger than the open gate (Fig. 11B) and rots less when made of wood. A concrete bulkhead opening into piping (Fig. 11A) is advisable in some places.

The outlet gate must be large enough to carry off the water of the heaviest rains and of flowages quickly.

Sand

Sand is used as a mulch before the vines are set and for resanding in after years. Fine sand promotes the growth of moss and allows weeds to thrive more than coarse sand. Sand screened from gravel is very satisfactory.

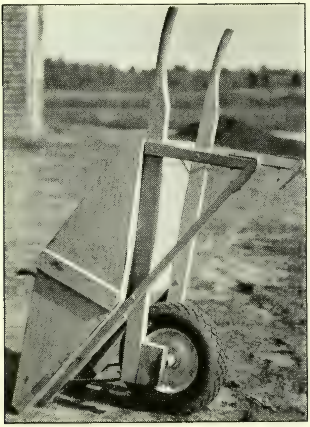

Fig. 12.

Wheelbarrow Used in Sanding Bogs.

On Cape Cod, where sand abounds around the swamps (Figs. 19B and 28), it usually is carried on to the bog over a line of planks by men with special wheelbarrows that have a pneumatic tire and balance the load over the wheel (Fig. 12); but railroads with gasoline locomotives and cars (Fig. 13) are often used on large areas. In Pacific County, Washington, where the sand underlies the swamps and is not available elsewhere, growers pump it up in water with a centrifugal pump and send it through piping, in some cases over half a mile.

The early bog makers on the Cape put on 5 or 6 inches of sand before planting. Some still do this, but the more experienced use only 3 or 4 inches. The vines grow faster with this smaller amount, the bog getting vined over and reaching full bearing sooner. Small stones in this sand do no harm.

A sanding rim may be made around the margin when the bog is built if the upland is mostly sand. This makes a good roadway and gives shorter hauls for resanding in after years than do scattered sand holes.

The sand helps check weeds and moss; it gives the cranberry roots a medium to grow in which can be drained and aerated far better than peat, so promoting their growth; it serves as a mulch and so ameliorates drouth; and it gives out heat at night so as to afford some protection from frost. Its pH is about 4.5 on most bogs in this State.

Varieties

Early Black and Howes are the varieties most grown on the Cape, to-

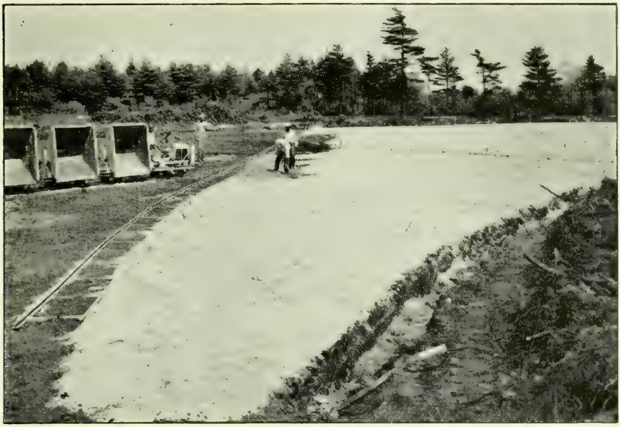

Fig. 13. Sanding a New Bog with Gasoline Engine and Cars.

gether making up 88 percent of the whole acreage. They are productive, well known to the trade, good keepers, and usually can be picked easily with scoops. Early Black berries (Fig. 14 A) make fine sauce, but Howes (Fig. 14 B), unless picked very late, are only fair in that respect. Early Black berries are preferred for canning and the variety will keep its lead a long time for that reason. Howes berries have a higher pectin content than those of any other cultivated variety. Howes ripen late and so interfere with proper fall flooding.

Bugle (Fig. 14 D), Centennial, Centerville, Holliston, Matthews, McFarlin (Fig. 14 C), and Smalley Howes are all fancy berries and prime for the table. McFarlin and Smalley Howes have found more favor than the rest of these varieties, the former being grown widely in Wisconsin and on the Pacific Coast. Aviator is the most promising of the newer varieties. Round Howes is perhaps the most productive variety.

McFarlin, Shaw's Success, and Early Black are quite resistant to false blossom; nearly all the other varieties are not.

Varieties with fine vines, short upright branches, and low seed counts and without a noticeable bloom on the fruit are generally superior in production and disease resistance.

A large number of new varieties, selections from the wild and crosses between cultivated varieties, are being tested for future planting by the Bureau of Plant Industry of the United States Department of Agriculture.

The varieties vary in ripening, the earliest usually becoming well colored the first week in September and the latest the third week in October. Some berries color well in storage; others will not redden much unless left on the vines. Most cranberries are first green, then whitish, then pink, then light red, and finally dark red. Some of the wild berries are white when ripe, and some cultivated ones get so dark red that they are almost black. The different kinds of berries vary in form, being pear-shaped, fusiform, oval, or round. The round berries are most easily sorted.

No flooding area should have more than one variety. Some of the leading varieties have insect or disease troubles which are especially bad with them, and the planting of other varieties on the same flooding area complicates controls.

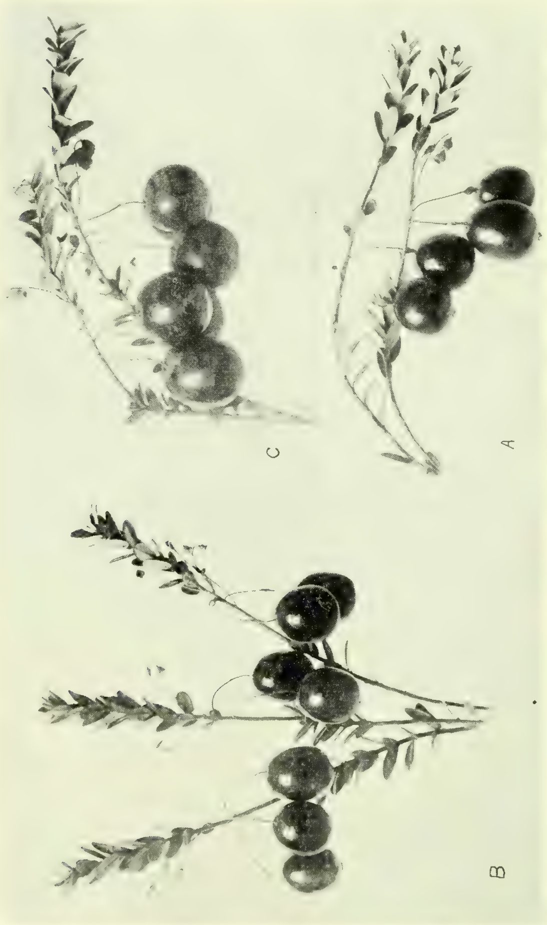

Fig. 14. Berries of Cranberry Varieties.
A, Early Black; B, Howes; C, McFarlin.

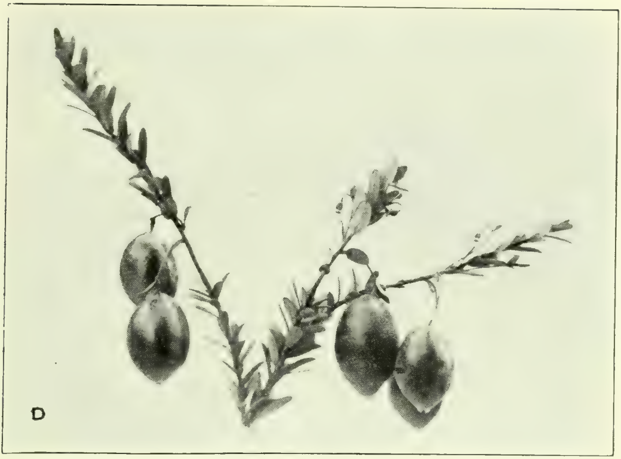

Fig. 14. Berries of Cranberry Varieties.
D. Bugle.

Vine Setting

The sanding should be done in April or May, for the vines set easier and grow better if they are put in before the sand packs. The bog should be marked for uniform planting in hills by drawing a marker with four or five teeth across it both ways (Fig. 15 A). The vines may be planted in late April, May, or early June, early May being best. They should be set 9 inches to a foot apart each way (Figs. 15 B and 7 A). With this spacing it takes 7 to 12 barrels of cuttings to plant an acre, according to the condition of the cuttings and the efficiency of the setters. The closer they are set the better they will anchor themselves against the pull of picking scoops.

The cuttings should be taken from a bog in good condition, free of variety admixtures, fireworms, gypsy moths, rose bloom, and false blossom, and with a record for producing good crops of sound fruit. If it failed to yield well the year before, all the better. The vines should be cut with a scythe and planted, if possible, soon after they are cut. If they must be planted in late May or later, they should be cut about May 10 and kept cool and wet till they are used. They may be stored loose under a tarpaulin in a cool shed and turned over and sprinkled every few days, or they may be spread out well in a stream or pond. They will lose their leaves and may die for want of oxygen if they are kept long in water in bags or bales.

Bogs from which vines are cut recover much faster if the cuttings are taken before growth starts. Experienced growers often refuse to cut vines for sale after the new growth appears. If the cuttings have a lot of new growth, much if it is likely to die and further growth will be slow

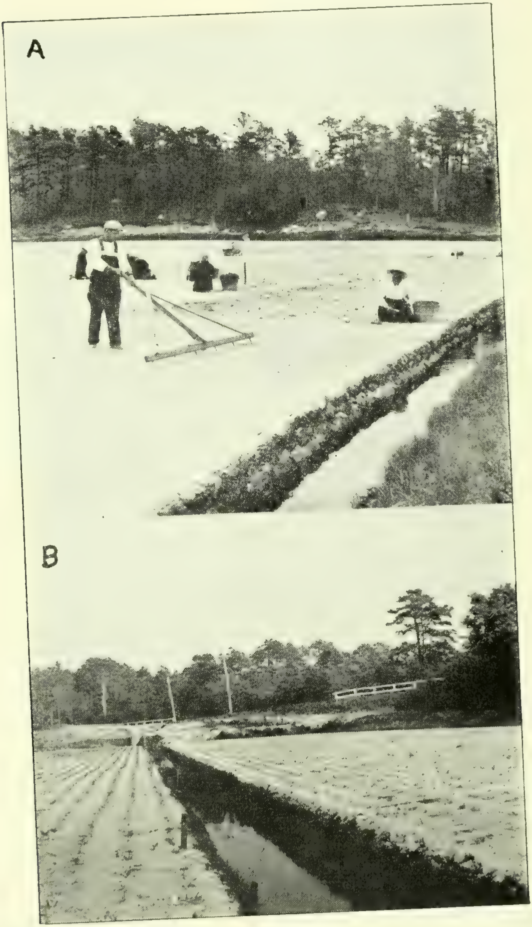

Fig. 15.
A. Marking Rows for Planting Cuttings.
B. A Newly Planted Bog.

for a time if it does. One who buys such vines cheats himself by paying for much unnecessary bulk.

If many vines are set in a bunch, those in the center die and are wasted. Two or three to a hill are enough. They must be pushed well into the sand but need not go into the peat beneath, for most of their

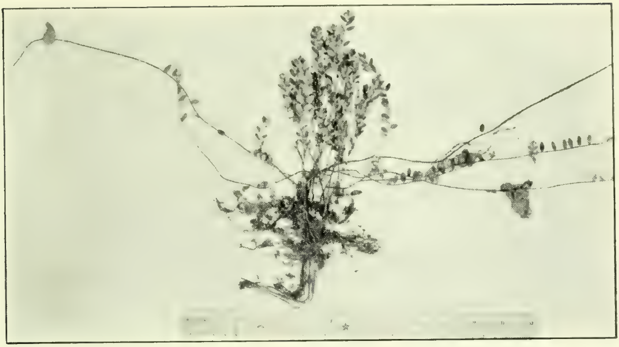

Fig. 16. Growth of Cuttings Set Two Years Before.
Few roots have started from the part of the stems in the peat, most of them growing in the sand covering. The two inches just above the bend were in the peat.

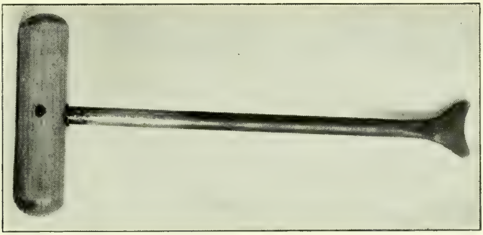

Fig. 17. Dibble for Planting Cuttings. It is eight to ten inches long.

roots will grow in the sand (Fig. 16). A wooden or iron dibble is used to press them in (Fig. 17). They need not stick up from the sand more than an inch. It often pays to hire professional vine setters.

Bogs are sometimes planted by scattering the cuttings evenly over the ground and covering them lightly with sand. This may save labor but it wastes planting material. Such plantings do well and come to bearing quickly.

COST OF BUILDING CRANBERRY BOGS

	Cost per Acre
Land	$ 10 – $100
Clearing, ditching, turfing, grading, and sanding	400 – 700
Eight barrels of vines at $4 per barrel	32 – 32
Planting vines	20 – 30
Incidentals (tools, dams, head-gates, buildings, etc.)	200 – 400
Total	$662 – $1262

The cost depends on the natural conditions and location of the swamp, on the ability and experience of the man who oversees the work, and on wages. A good bog, well located and built, planted with the right varieties, and given good care, should be nearly permanent. There are bogs on the Cape over eighty years old and still in good condition. To own and properly manage a cranberry property requires a considerable investment and special experience which it takes years to acquire.

CARE OF A NEWLY PLANTED BOG

Water should be put on right after planting, held near the surface a day or so to wet the vines and pack the sand around them, and then drained to the bottoms of the ditches. If the bog is flowed again the first season, it should be only for a day or two to wet the sand or control insects.

New bogs should be flooded for the winter as soon as the ground begins to freeze, for frost in the soil heaves new sets out. The surplus water must be let off at times of thaws or heavy rains in winter or early spring. If this is neglected with the vines frozen into the ice, the raising of the ice will pull them out of the ground.

The first three years the winter flowage should be let off about May 5. Earlier removal exposes the plants to possible frost heaving.

More weeds grow on a bog the first two or three years than later, for the vines have not grown enough to crowd them. They give relatively little trouble afterward if they are kept down then. A grower should know the weeds he has to fight at this time, for it is enough to mow the tops of some kinds (most rushes), and some (rice cut-grass) can be checked by good drainage, while others must be rooted out or killed with salt (ferns, brambles, hardhack, leather leaf, and sheep laurel) or kerosene (grasses and sedges). Upland weeds often appear on new plantings; they need not be heeded, for they will die in the winter flood.

After the first year and before it comes to bearing, the new planting should be flooded several times each season to check insect pests.

Constant roguing is necessary the first three years to remove plants of odd varieties and hills with false blossom.

The new bog should be resanded with two thirds of an inch of sand right after the first crop is gathered to make the vines develop a strong root system and become well anchored.

It costs $200 to $400 an acre to care for a new bog till it crops.

CARE OF A BEARING BOG

A new planting usually comes to bearing the fourth year, and its care thereafter is described below.

The Use of Water for Flooding

Cranberry vines often winterkill, sometimes to the ground, when exposed for a week or more to drying winds with the soil around their roots frozen. This is due to desiccation, the plants being unable under these conditions to replace the water given off by the leaves. It usually occurs before midwinter but may occur at any time from early December to late March. Flooding for the winter is the best protection.

The winter flowage should go on as soon as the sand surface remains frozen all day, usually about December 1 on the Cape. The water should be held just deep enough to cover the vines. It is often best to let the highest parts stick out when a bog is much out of level. The vines are as well protected frozen into the ice as any way, though sometimes they are pulled badly if they are not well anchored and if the ice is thick and is lifted by water. Heavy ice sometimes does some harm by breaking off the vines where it cracks; this injury appears in the spring as though a cleaver had severed the vines and cut into the ground beneath them.

If the bog can be reflowed, the winter water should be let off about April 1 two years out of three. It may be held till May 23 the other years[10] to control the fruit worm and false armyworm, reduce weeds and fungous diseases and promote vine growth. It must not be held so late if it is deep over much of the area or the vines are over vigorous. It may be held till about May 20 rather regularly on bogs that cannot be reflowed. Holding after May 25 invites cutworm infestation. Algal scum often develops in the flood water when it is held late. This sometimes dries to form paper over the vines after the water is let off and is then harmful (Fig. 18). It can be prevented from forming by dissolving 4 pounds of copper sulfate to the acre-foot in the flowage about the first of April. Coarse crystals of the chemical in a burlap sack may be towed in the water behind a canoe. Changing the flood water early in April, exposing the bog to air a week or more, also usually prevents this trouble.

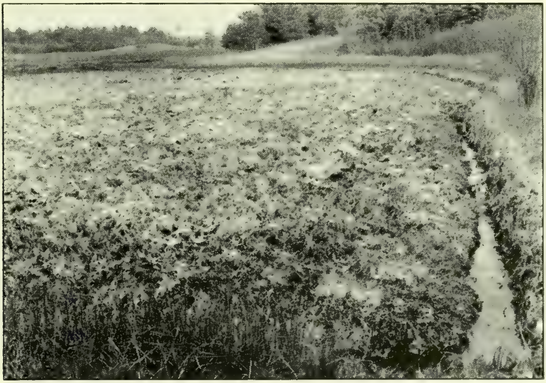

Fig. 18. Cranberry Bog Covered with "Paper" from Algal Scum.

Bogs used to be flooded regularly early in June to check insect pests. This is advisable one year in three but is a dubious annual practice for it carries fungous infection to the new growth, promotes fireworm infestation, and sometimes reduces the crop seriously by drowning the flower buds. This flood should go on in the night and also be taken off at night if the weather is very warm, for if tender growing vines stand in water long, exposed to a hot sun, they may scald. The flower buds are less likely to be hurt by the flooding if the weather is clear while the water is on, for light is necessary to the photosynthesis by which the plants give oxygen to the water. Cloudiness with a high water temperature is especially dangerous, for the warmer it is the faster the plants respire and the greater their need of oxygen. The complete flood should not be held on a bog over thirty hours unless the weather is definitely clear and cool and should not be held over twenty hours if the bog has a bad record of injury by June flooding.

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[10] It probably is better to let the winter flowage off early in April, reflood about April 25, and hold the water till May 23, than to hold the winter water late. This serves all the purposes of late holding, airs the vines, and gives time to work on the bog.

A partial flood must be put on if frost threatens in May or June. Two or three inches of water under the vines is enough, for heat will pass from the water to the air and keep the vines from freezing. If water must be saved and it remains cold, the water may be held over on the bog from one night to another for several successive days up to about May 12 and for a day at a time occasionally after that.

Cranberry winter buds are not hurt by a temperature of 25° F. till they swell to a diameter of more than 2 mm. They usually will endure temperatures down to 20° till the end of April. Temperatures above 29° seem never to do much harm. Often 28° is reached in the time of tenderest growth without injury, but the greatest depression in such cases is brief.

Flooding should not be done during or after the blooming period, for it will blast the blossoms and promote rapid development of the fungi that rot the fruit.

Frost in September and October often necessitates flowing again, but the berries and vines will endure more frost then, and longer chances may be taken than in the spring. The water may be held over on the bog from one night to another occasionally, as in the spring, if it seems necessary. Cranberries usually will stand 27° F. in the whitish stage before ripening, but 25° harms such fruit greatly. Freezing begins among ripe Early Black and Howes berries at or slightly above 22°, no softening following exposure to 23°. Ripe Howes and McFarlin berries are so resistant that under bog conditions often only 10 percent are injured at 16° and only 20 percent at 14°. Sometimes, however, 25 percent are softened by 18°. The loss of Early Black berries at these temperatures is much greater.

Frost flooding always does some harm: in the spring tending to reduce production, and in the fall tending to impair the keeping quality of the fruit and interfering with harvesting. For this reason and because unnecessary frost flooding wastes limited water supplies, accurate forecasts of frosts are very important. The Weather Bureau sends out special warnings to the cranberry growers, which are supplemented by those of the Cranberry Station of the Massachusetts Agricultural Experiment Station.

As soon as the crop is gathered, the bog should be flooded for a week to water the disturbed roots and float off fallen leaves, berries, and other trash.[11] This controls the cranberry girdler when it is done late in September. No flooding is necessary after this till the water goes on for the winter.

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[11] If much of this material lodges on the vines, it is very harmful. There should be catch basins around the bog margin to receive it from the flood. If no catch basins have been made, the trash must be raked from the water where the wind drives it ashore.

Some bogs can be flowed only for the winter and some are not flowed at all. They generally are not so profitable as those with plenty of water, but some of them pay well under good management.

Sand and mud wash into the ditches and growing weeds and floating materials help to fill them so they must be cleaned out every few years.

Irrigation

Bogs are too wet oftener than too dry. They do, however, sometimes suffer from drouth, the berries being reduced in number and size and the vines dying in severe cases. Practice varies in bog irrigation. Occasional light flooding for a few hours at night followed by complete withdrawal of the water is perhaps better than holding the ditches full a long time in the growing season. This is certainly true where density of the soil makes it difficult to irrigate from the ditches. Watering with a sprinkling system, though costly, is effective for both irrigation and frost protection and will be done more on cranberry bogs.

The Use of Sand

As the cranberry roots form a dense growth in the sand over the peat, they become soil bound, and resanding gives them more soil to grow in. Largely on this account, resanded vines are generally thriftier and more productive than those not resanded. Moss and fallen cranberry leaves are poor conductors of heat and bogs not resanded regularly are commonly well covered with such material and so very liable to frost injury.

The oftener resanding is done the more it protects against frost, the girdler, the green spanworm, and the tip worm; but bog conditions should determine its frequency. Bogs with little water for reflooding should be resanded every other year or every year lightly; those with plenty of water for frost and insect flooding and with a moderate vine growth should be resanded every third or fourth year; and those with ample water supplies and heavy vines never should be resanded. From a quarter of an inch to an inch of sand, according to circumstances, is put on at a time, being spread with square-pointed shovels. Experienced men are needed for this job.

Sanding may be done most cheaply in the winter (Fig. 19 A) with favorable weather, but there is not enough ice for this on the Cape in more than one year in three. Considerable injury is done to the vines by resanding in the early spring and it increases rapidly as the season advances; resanding should not continue after May 5. Help is generally more plentiful in the fall and better attention can be given this work then. Whenever it is done, it usually reduces the following crop noticeably. The tops of the vines must be raked up out of the sand wherever they get covered too much with it. Ice resanding is done mostly with trucks; spring and fall resanding, with wheelbarrows (Fig. 19 B and C) or cars (Fig. 13). The cost of properly applying a third of an inch of sand varies from $15 to $50 an acre.

All stones must be screened from the sand before it is used, or collected from the bog afterward, else they will bruise the knees of pickers and be gathered with the berries in scooping. Bog gang screens, 6 feet by 3 feet or larger, and individual wheelbarrow screens are used for this, a three-quarter inch or inch mesh being best.

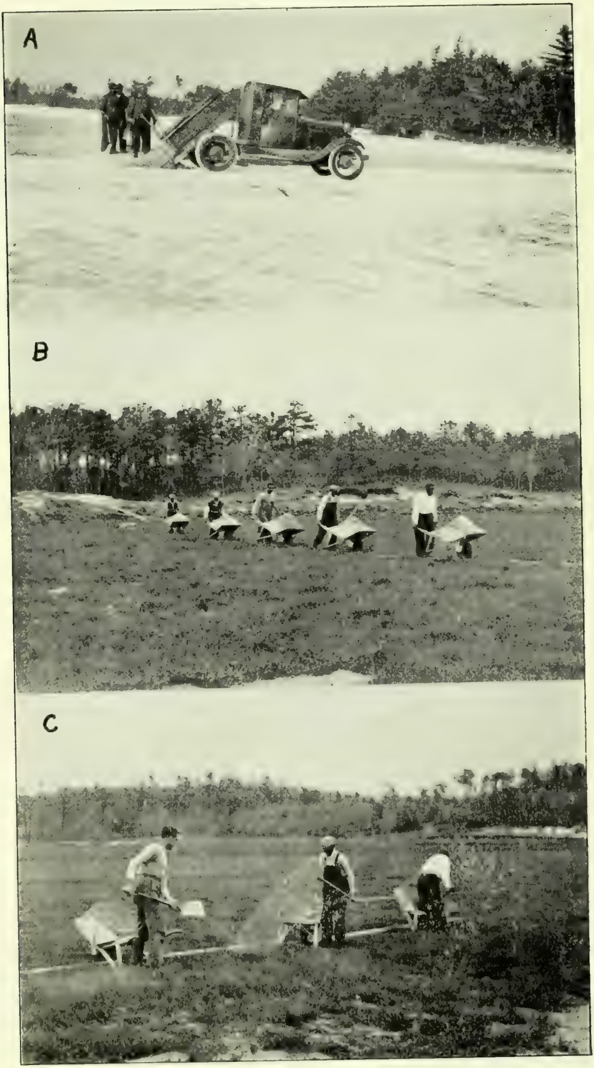

Fig. 19.
A. Resanding with Trucks on the Ice of the Winter Flood.
B and C. Resanding with Wheelbarrows.

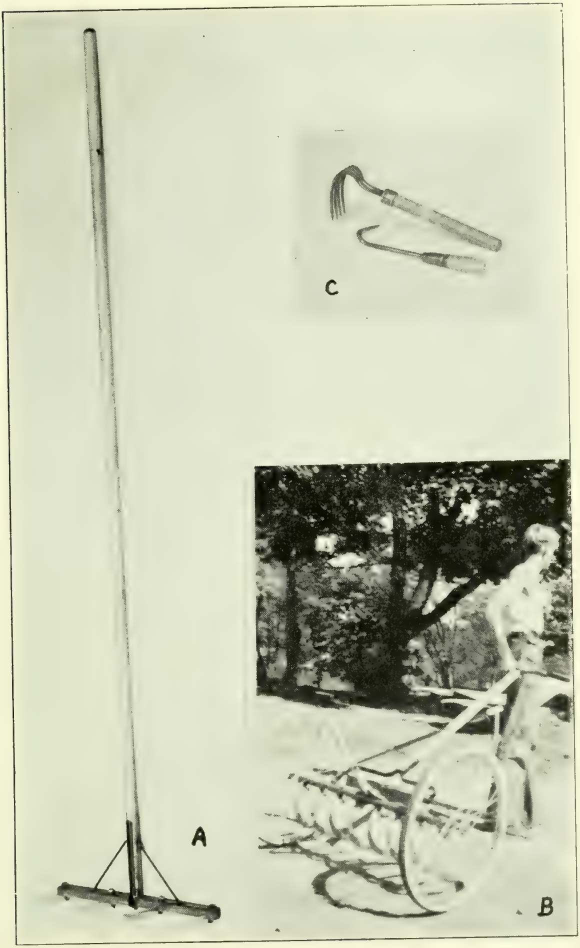

Fig. 20. Cranberry Tools.

- A. Cranberry Knife Rake. The blades may be detached for sharpening.
- B. Machine for Pruning Vines. It is drawn by hand along and then across the bog and is very useful if the blades are kept sharp.
- C. Bog Weeders.

Pruning

Vines often grow too thick and tall, especially on new bogs with a rich bottom and a thin sand covering. The runners that float over the tops of the vines after harvesting must be cut off carefully with a knife rake or pruner (Fig. 20 A and B). Experienced men should do this work, for it is often very harmful when done carelessly. No other cranberry pruning is advisable. The vines should be mowed with a machine if they are so heavy that fruit production is much reduced. They will be even and usually less rank when they grow again. Some burn off heavily vined bogs, but the burning may harm the roots, the vines are slow to come to bearing again, and the bog is more exposed to weed growth.

Fertilizers

No advantage is gained by fertilizing peat-bottom bogs. Nitrate of soda and acid phosphate often greatly increase the yield on "hard bottom" areas (sand or clay underneath instead of peat), and 150 pounds of the former and 300 pounds of the latter to an acre is a reasonable application Potash has little value on any bog. Mid-June, when the spring frost-flooding is past and the vines are beginning to bloom, is probably the best time to apply fertilizer.

Nitrate is likely to promote too much vine growth on peat bottom, especially if the bog is new. It is generally better to get more vines, where they are desired, by holding the winter flood late than to fertilize for them. Continued use of nitrate impairs the keeping quality of the fruit and encourages weeds.

Fertilizer helps greatly to repair old bogs out of condition from grub injury. Reground nitrate of soda scattered broadcast early in April, 250 pounds to an acre, reduces haircap moss well and helps the vines compete with it.

Diseases[12]

Many fungous diseases attack cranberries. Some seriously affect the vitality of the vines or cause the leaves to drop and some reduce the crop by blasting the blossoms and young berries or by rotting the berries on the vines and in storage. Late holding of the winter flood (to May 23) and good drainage during the growing season curtail such troubles. Bordeaux mixture reduces rot of the berries on the vines and improves their keeping quality; it has been very helpful in some cases, but whether its use generally pays in this State is doubtful. Lead arsenate also has this effect, but its frequent use weakens the vines on sanded areas. Care in handling the fruit in harvesting, separating, sorting, and packing does much to reduce decay in shipment.

The rot diseases of cranberries caused by different fungi vary greatly in their prevalence in the different cranberry-growing regions of the country. Early rot, which blasts the flowers and young berries and rots the fruit on the vines and in storage, is the most serious of these troubles in New Jersey. As this disease is more completely controlled by spraying with Bordeaux mixture than the others, this treatment is especially valuable in New Jersey. Bitter rot, which rots some berries on the vines and more in storage, and end rot are the leading cranberry rots in Massachusetts. End rot, a late storage rot, is the only serious cranberry rot in Wisconsin and on the Pacific Coast. The relative scarcity of the earlier rots accounts largely for the success of the Searls variety[13] and of water scooping in Wisconsin and for the greater popularity of the McFarlin variety in the West than in the East.

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[12] Technical Bulletin No. 258 of the United States Department of Agriculture is the best general account of cranberry fungous diseases. Extension Leaflet No. 154 of the Massachusetts State College discusses false blossom.

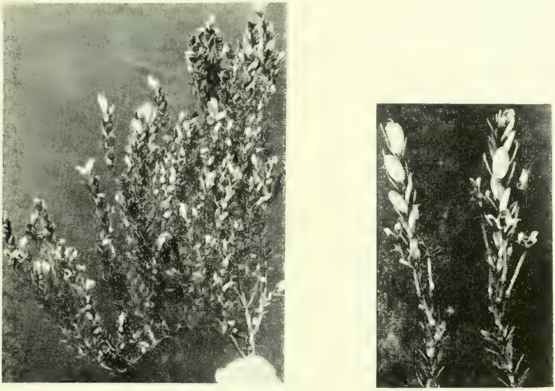

Fig. 21.
LEFT: Witches' Broom Growth Caused by the False Blossom Disease.
RIGHT: Flower Development of Vines with False Blossom.

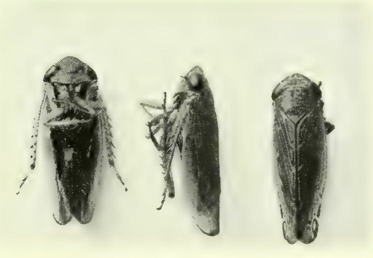

Fig. 22. Blunt-nosed Leafhoppers.
This insect carries the false blossom disease.

New bogs never should be planted with vines having either false blossom or rose bloom. These are the important non-putrefactive cranberry diseases. Both often greatly lower the vitality of the vines and reduce fruit

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[13] This variety has not succeeded in the East because of the rotting of its fruit here.

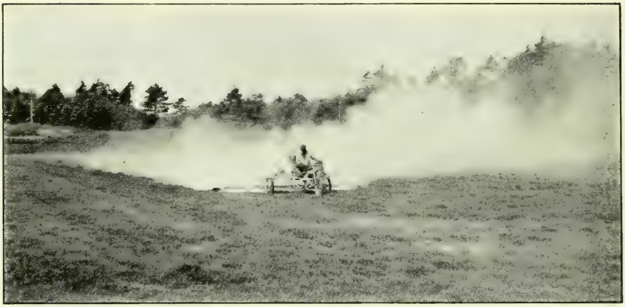

Fig. 23. Dusting to Control Insect Pests.
It is sometimes advisable to use an airplane for this work on large bogs.

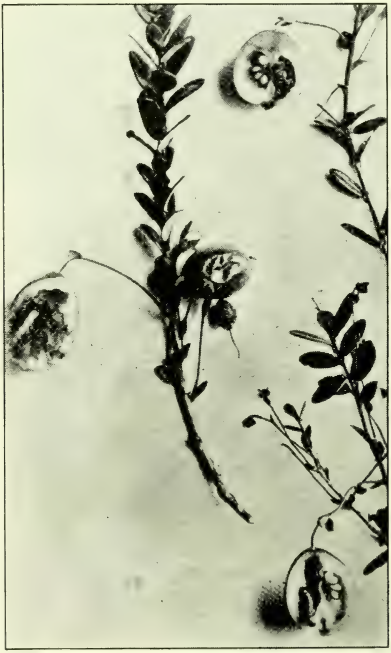

Fig. 24. Cranberry Fruit Worm.
Berries cut open to show worms at work.

production. Vines affected by false blossom come to have a witches'-broom development (Fig. 21 left), and their flowers open facing upward (Fig 21 right) instead of turning down as healthy cranberry blossoms do. It is a virus disease, spread by a leafhopper (Fig. 22), and can be controlled by checking the leafhopper with pyrethrum dust or dusts containing rotenone (Fig. 23). Rose bloom is a fungous disease which causes new shoots to be greatly enlarged and rose-colored, the vines sometimes appearing as though they were in full bloom. It affects late varieties most, especially Matthews and Howes. It may be treated by flooding for thirty hours or by spraying with Bordeaux mixture, 10 pounds of copper sulfate and 4 pounds of lime to 100 gallons of water, 250 gallons an acre, or with basic copper arsenate, 6 pounds in 100 gallons of water, 250 gallons an acre, about May 25. (H. F. Bergman.)

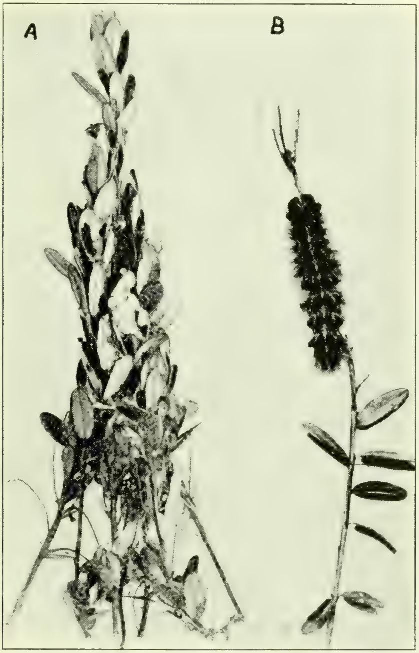

Fig. 25.

A. Webbed Cranberry Branches, work of the Black-headed Fireworm.
B. Gypsy Moth Caterpillar Defoliating a Cranberry Branch.

Insect Pests[14]

The chief cranberry pests in order of their importance are: the fruit worm, the black-headed fireworm, the blunt-nosed leafhopper (carrier of false blossom), the root grub, the gypsy moth, and the girdler.

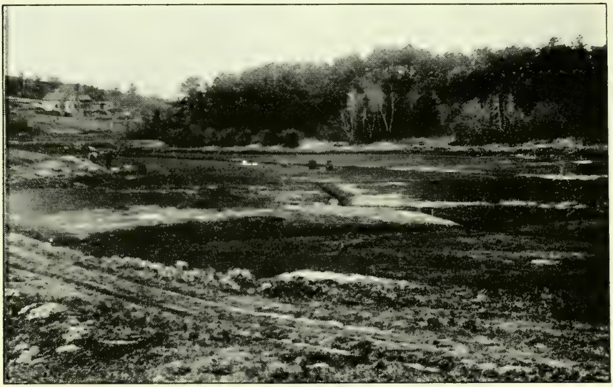

Fig. 26. Cranberry Bog Infested with Root Grubs.
The bare patches are a result of their work.

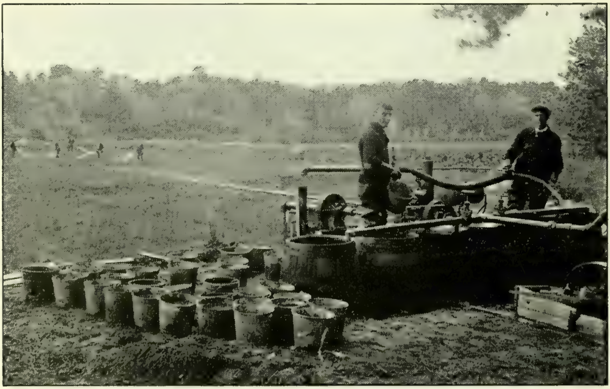

Fig. 27. Treating Root Grubs with Sodium Cyanide Solution.

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[14] The best discussions of cranberry insects are Farmers' Bulletin No. 860 of the United States Department of Agriculture and Bulletin No. 239 of the Massachusetts Agricultural Experiment Station. Neither of these is nearly up to date in treatments. The extension services of Barnstable and Plymouth counties (with offices at Barnstable and at 106 Main Street, Brockton, respectively) issue a cranberry insect and disease control chart and a weed control chart every spring.

The fruit worm (Fig. 24) has taken an estimated third of the whole Cape crop in some years. It may be checked by holding the winter flowage till late May or by spraying or dusting late in the blossoming period and again 10 days later with derris or cryolite.

The black-headed fireworm (Fig. 25 A) seldom harms strictly dry bogs much. It was formerly treated largely by flooding in late May or early June. This is usually effective for the time being, but its usual long-range effect is to promote the continuance of the infestation. Dusting with pyrethrum or with dusts containing rotenone is very effective.

Small patches infested with root grubs (Fig. 26) are treated with a solution of 6 ounces of sodium cyanide in 100 gallons of water, a gallon to a square foot (Fig. 27). This is fairly effective but must be repeated in 10 years. A much more permanent treatment is to let the winter flowage off early in April, reflood about May 12, and hold the water till July 10. This usually cleans out grubs of all kinds thoroughly, but at the cost of the crop.

The gypsy moth (Fig. 25 B) may be controlled by holding the winter flowage till May 25, by reflooding about May 25 for 36 hours, or by spraying with 3 pounds of dry lead arsenate in 50 gallons of water about May 20. Fooding for 12 hours kills the worms after they are a third grown. High grade pyrethrum dust, 100 pounds to an acre, or a spray of 15 pounds of derris (4 percent rotenone) and 2 pounds of soap in 100 gallons of water, 400 gallons to an acre, destroys the maturing worms. The maturing worms must be kept from getting on a bog by removing all deciduous trees for some distance from the margin and by keeping the marginal ditch cleaned out and partly full of water, with a film of fuel oil on the water.

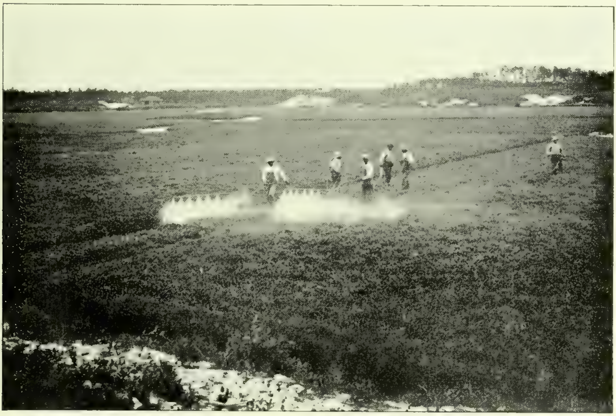

Fig. 28. Spraying to Control Cranberry Insect Pests.
Note the long line of hose handled by the men. The spraying machine is always on the upland near the bog margin.

The cranberry girdler seldom infests areas kept well sanded; it works chiefly in the trash of unsanded bogs among thick vines. Complete flowage after picking, beginning by September 25 and continuing for a week, is a good control. Complete flooding for about 20 hours, the last of August or early in September, to check a severe attack is sometimes advisable, especially with the Howes variety. A serious infestation can be largely controlled by dusting with pyrethrum, 50 pounds to an acre, two or three times at four-day intervals in early to mid-June to kill the moths.

Both the brown spanworm (hatches late in June) and the false armyworm (hatches May 8 to 12) can be checked by spraying when the worms are hatching with 3 pounds of dry lead arsenate in 50 gallons of water (Fig. 28). The latter is also controlled by flooding for 10 hours.

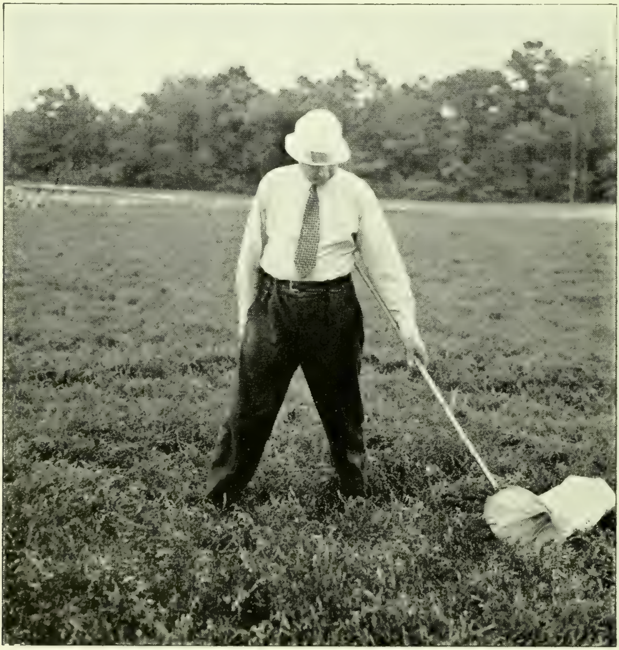

Fig. 29. Examining a Bog with an Insect Net.

The yellow-headed fireworm attacks only bogs without flowage. It is checked easily by spraying with 3 pounds of dry lead arsenate in 50 gallons of water, 250 gallons an acre[15], about May 22 or about July 13.

The last brood of the tip worm sometimes does much harm where the vines are not thrifty by reducing the bud formation for the crop of the following year. Resanding every other year controls this insect well on most bogs, but a bog should not be sanded so often for this alone.

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[15] This is the amount to use of all lead arsenate sprays on cranberry bogs.

Growers should sweep their bogs with a net every few days till midsummer to find and gauge insect infestations (Fig. 29). It often does not pay to treat a light infestation, especially if the crop promises well, because of the mechanical injury involved. Counts of less than 9 gypsy moth caterpillars or cutworms or less than 36 spanworms to 50 sweeps of the net may be disregarded. Over 3 blunt-nosed leafhoppers to 50 sweeps should be treated.

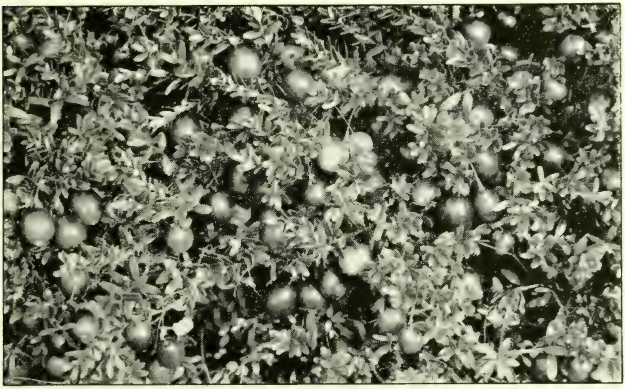

Fig. 30. Early Black Cranberries Ready to be Picked.

Weeds[16]

All weeds should be removed from a bearing bog by the time the vines bloom; and if sedges, rushes, cotton grass, or cut-grass appear later, they should be cleared out again, regardless of the injury done in weeding. Late fall and early spring, when the vines are dormant, is the best time to dig out such woody weeds as hardhack, chokeberry, sheep laurel, leather leaf, and poison ivy and any weeds that may be green then (Fig. 20 C).

Water-white kerosene, 300 to 600 gallons an acre applied as a spray or with a watering pot the second week in May, is a good control for grasses, sedges, rushes, loosestrife, alders, and brambles. Iron sulfate, used dry in July, controls sensitive and feather ferns and tear-thumb. A spray of 20 pounds of copper sulfate in 100 gallons of water, applied 400 gallons an acre in mid-August, is the best treatment for nut grass. This spray, applied 600 gallons an acre early in the spring or late in the fall, kills haircap moss well. Ditch weeds and undesirable growths on the uplands are killed with a spray of 15 pounds of sodium arsenite in 100 gallons of water.

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[16] Cranberry Canners, Inc., has recently published a handbook on cranberry bog weeds. It is splendidly illustrated with photographs.

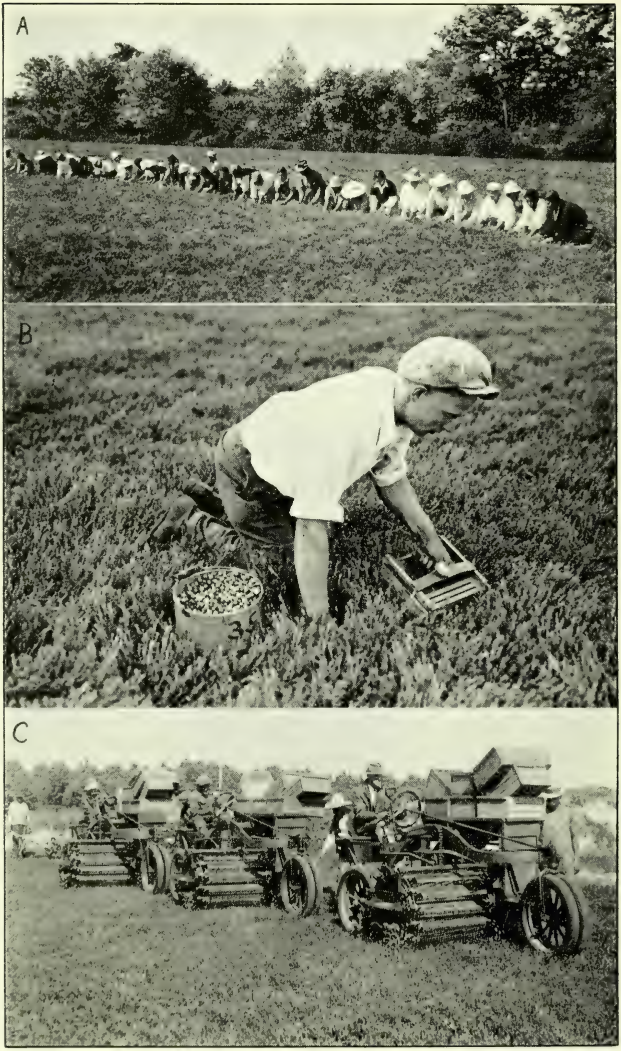

Fig. 31.

A. Picking Cranberries by Hand. B. Picking with a Snap Machine.
C. Harvesting Cranberries with Power Machines. One machine picks two acres a day.

HARVESTING

Cranberry harvesting generally begins about Labor Day and continues till about October 20 (Fig. 30). The harvest period is so short that many growers, especially if the season is late, have to begin when the fruit is only partly colored. Early Black berries keep best if they are picked before they are fully red. They usually should be gathered the second week in September. The later Howes are picked, the better they keep; it is often best to gather them late in September, but they should be left on the vines till the second week in October where bog conditions allow it. Other Massachusetts varieties are harvested as follows: Black Veil, the first week in September; McFarlin, Bugle, Centerville, and Centennial, the second or third week in October. The berries grow sweeter and larger as they ripen, so the later they are picked, the better the sauce they make and the greater the yield.

Cranberries should be gathered only when the vines are dry. A frosty night compels the flooding of unpicked areas, and usually little harvesting can be done the next day. Berries picked late in the afternoon keep better than those gathered in the heat of the day.

Cranberries were picked by hand at first, and it took an army to gather the crop. Some hand picking is still done on the Cape (Fig. 31 A), but it is an expensive and probably unwise practice except on thin or poorly anchored vines where scoops do too much harm. Small but effective devices known as "snaps" (Fig. 31 B) are often used to gather the fruit on new or sparse vines. Power machines (Fig. 31 C) have been used considerably but are not widely favored.

The Cape Cod and Wisconsin crops are now picked mostly with scoops (Figs. 32 and 33 B). Hand picking is more common in New Jersey. Fair

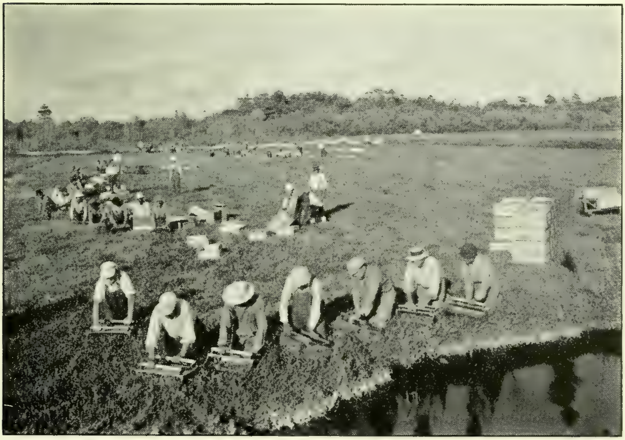

Fig. 32. Scooping Cranberries.
One man sometimes scoops fifteen barrels in a day.

crops can be scoop-picked for from 60 to 90 cents a barrel. Heavy crops have sometimes been scooped for 9 cents a barrel, but they can hardly be gathered so cheaply, even under the best conditions, without great waste, too much of the fruit being left under the vines when the scoopers are rushed, especially when the crop is heavy. Fully a fifth of the whole Cape crop is left on the bogs in this way.

To have the pickers work steadily, without haste and with as little waste as possible, is a good rule. If help is scarce and water supplies are low, however, it sometimes is best to pick the crop hastily to save it from frost, great though the waste. The speed with which scooping should be done

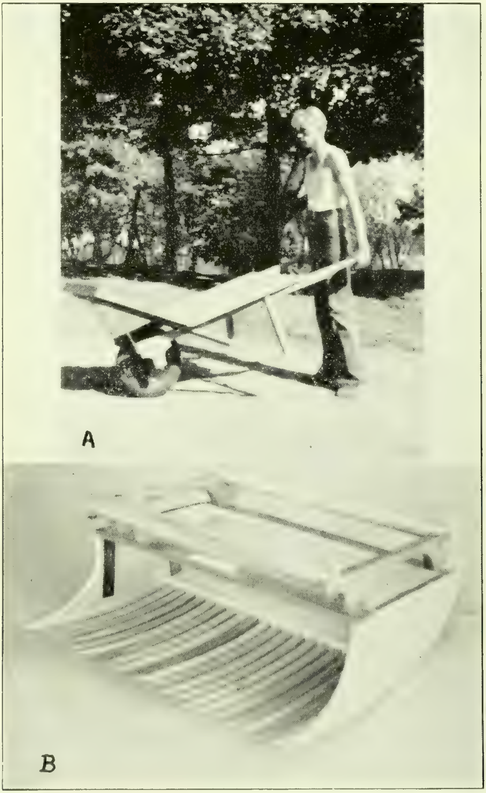

Fig. 33.

A. Special Wheelbarrow for Taking Boxes of Berries from a Bog. It is better than it looks.
B. A Cranberry Scoop. A picker can work steadily with one of these till it is nearly full. It holds about half a bushel.

also depends on the crop and on prices; $5 a barrel justifies rapid scooping unless the crop is heavy; but $8 or more with an average crop calls for careful work.

It ordinarily is best to pay the scoopers by the hour. They may be hastened with bonuses. Their wage has ranged from 35 to 75 cents an hour. Picking by the box is done widely, and wisely, for it attracts the more experienced and efficient scoopers. Twenty-five cents a bushel box was a common 1939 wage.

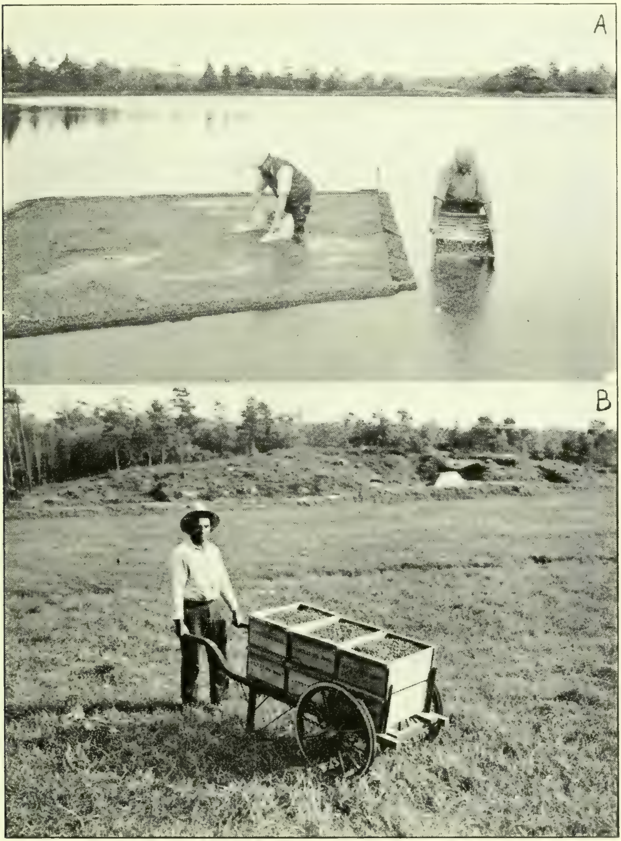

Fig. 34

A. Gathering Floaters from a Bog Flowage. They are first assembled with planks.
B. Wheelbarrow Loaded with Full Picking Boxes. These boxes are usually about $19\frac{1}{2}$x14x8 1-3 inches, inside measure. Note the slat handles at the top of each.

It never pays to gather by hand the berries that fall to the ground. They always are in poor condition, having been tramped over more or less, and will decay quickly. Such berries are often taken from the water as flotage on the after-picking flood (Fig. 34 A), but most of them are held under by the vines. Those so gathered are cleaned of trash quickly and completely while wet, with screens made for the purpose. Most of them are sold to canners.

The berries as they are picked are dumped into bushel boxes on the bog, the boxes having slits in the sides and bottom for ventilation and slats at the ends for handling and for spacing in stacking (Figs. 34 B and 35 A). Many vines gathered by the scoops go into the boxes with the berries. It is widely supposed that the berries store better if the vines

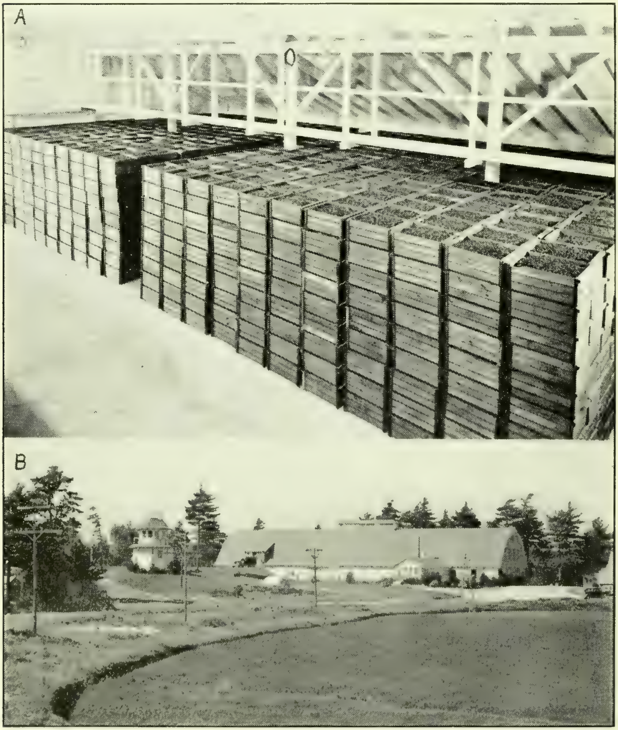

Fig. 35

A. Picking Boxes Full of Cranberries Stacked in a Screen House.
B. An Up-to-date Screen House, with part of a bog in the foreground.

and chaff remain in the boxes with them, it being thought that they aid ventilation; but the vines have no such effect and unattached leaves promote decay. Sand picked up in the scooping is very harmful among the stored berries. Stones gathered with the berries bruise them as they are picked and when they go through the separator, impairing their keeping quality.

A foreman, 13 scoopers, and 3 helpers are needed to pick a 15-acre bog. Two of these men carry empty boxes to the pickers and take the full boxes from the bog and stack them on the upland for trucking. Special wheelbarrows with pneumatic tires (Figs. 33 A and 34 B) are best for removing the berries from a bog.

After the crop is harvested, the vines are raked lightly with hand hay rakes in the direction opposite to that in which they were scooped. This clears the bog of loose material torn up by the scoops and trains the vines for the next year. A market for the rakings as a mulch is developing rapidly. Dry bogs should be picked with snaps and be raked early in the following spring, for the less the vines are disturbed in the fall, the less liable they are to winterkill.

STORAGE

The berries are stored in the packing house (screen house) in the picking boxes as they came from the bog (Fig. 35 A). The building, if tightly constructed, should be kept close shut on damp and on warm days and be well aired on cold nights, with fans if necessary. It should have capacity to hold two-thirds of the maximum crop expected from the bog and a proper supply of shipping boxes and shooks, as well as room to sort and pack the fruit. A building of one floor, 40 by 70 feet, is large enough for a 12-acre bog. Open sheds are cheap and make good storage. Cellars are less satisfactory except in protection from freezing. The most modern cranberry storages (Fig. 35 B) are lined with insulating materials to maintain a moderate temperature. Cold storage for this fruit is practicable. The berries keep best at a temperature of 35° F. but they color best at from 45° to 50°. They keep and ship better after cold storage than after common storage.

PREPARATION OF THE BERRIES FOR MARKET

The first shipments usually go out within a week after picking begins, in early September, and the crop is nearly all sold by Christmas, though the growers often hold some fruit till after midwinter. Many prefer to take the lower prices which the earlier shipments usually bring and get rid of their berries promptly. Their fruit does not suffer the shrinkage that late-shipped berries do, and the cost of sorting is much less. Some, however, prefer to take these losses and gamble for higher prices. This seems to have been increasingly risky in recent years.

In preparation for market, the berries first go through a separator. There are several makes of these machines. Those used on Cape Cod and largely elsewhere (Figs. 36 and 37) have a hopper at the top to receive the berries, a blower to clean them of chaff, several bounding boards to separate the decayed from the sound fruit, and a grading device.

Much of the fruit of the early shipments is often so sound that it may be packed for shipping as it comes from the separator. Most of the berries,

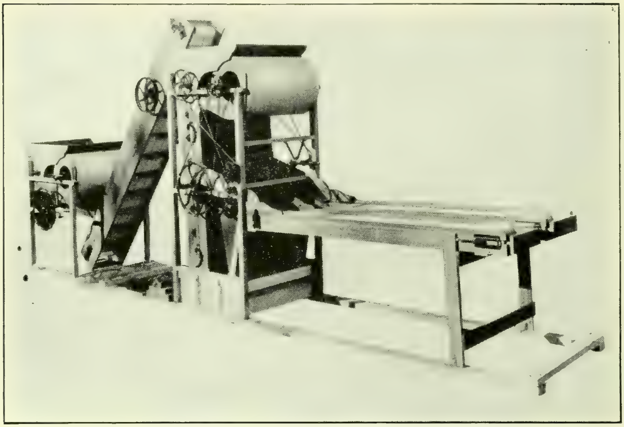

Fig. 36. A Cranberry Separator, with Extra Blower and Elevator at the Left and Sorting Belts at the Right.

The extra blower makes the flow of berries through the separator more even; a two-inch mesh wire screen in the hopper takes out vines.

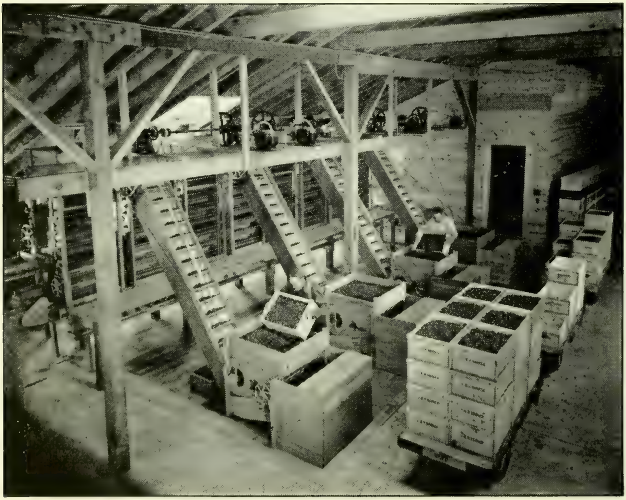

Fig. 37. Screen-House Scene.

A floor truck loaded with picking boxes full of berries at the right in the foreground. Four extra blowers and elevators, in the center, feeding a battery of eight separators at the left. Rows of shipping boxes at the right in the rear.

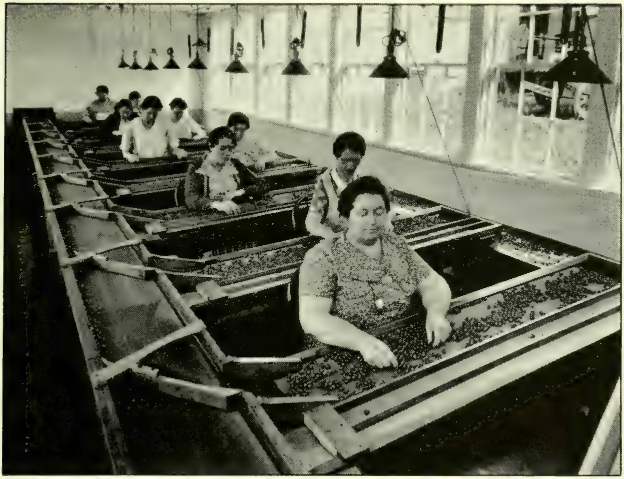

Fig. 38. Hand Sorting Cranberries on Moving Belts.
Green or whitish berries and berries showing frost injury or decay are picked out.

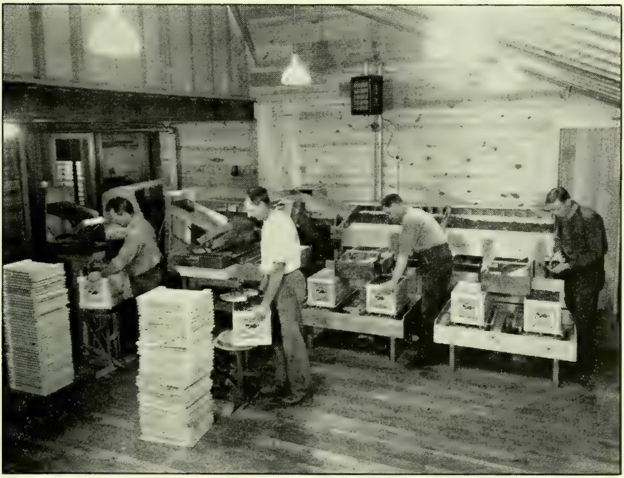

Fig. 39. Packing Cranberries in Shipping Boxes. Inspector at right.

however, must be hand-sorted. Women do this work, mostly on moving belts (Fig. 38), in a well-lighted and comfortably warm room which is walled off from the cooler storage and packing rooms. The berries pass through this sorting room too quickly to warm up much. Sorters are paid 25 cents an hour.

It is best not to sort or pack the berries on wet days, for they collect moisture in damp weather and are more likely to rot in transit if they are packed moist. The fruit was formerly shipped mostly in barrels, but now the quarter-barrel box is used almost entirely. The cranberry barrel contains about 90 dry quarts, its dimensions being fixed by law. The containers must be shaken well and the berries heaped slightly and pressed down in packing (Fig. 39) so that they may not come to market "slack-packed." Slack-packed berries are shunned by the trade because they lack in quantity and their keeping quality is impaired by thrashing.

MARKETING

The fall opening price of cranberries ranges from $4.50 to $13.00 a barrel according to conditions. The price sometimes has risen to over $30 a barrel in the winter.

Over half the Cape crop is sold through a co-operative, the New England Cranberry Sales Company[17]. Other companies in Wisconsin and New Jersey, affiliated with the New England company in the American Cranberry Exchange[18], handle most of the berries from those states. This organization is well managed and helps the trade greatly by extensive advertising and by watching the cranberry markets throughout the United States and Canada and distributing the berries as they are needed, so preventing gluts. It has central packing houses and experienced inspectors, and the berries it handles are tested for keeping quality in incubators and packed uniformly under different brands according to their varieties and qualities. It establishes opening prices, basing them on careful studies of conditions, and pools most of its fruit. It has fostered research which showed that cranberries have important healthful properties, and distributes selected cranberry recipes gratis.

There are also a few independent distributing agencies, some of them very efficient. Much of the fruit sold outside of the Sales Company goes to commission men. Buyers for cash are around every year.

PRESERVING

Owing mainly to the enterprise and energy of the cranberry growers directing the cooperative Cranberry Canners, Inc., the preserving of this fruit has become a great industry (Fig. 40). Nearly its whole development has taken place since 1923. Now almost a third of the crop of the country goes into cans as sauce or into bottles for beverages. Some of the fruit is dried, but this excellent product has found only particular and limited markets. Most cranberries of doubtful keeping quality now go to preservers, leaving only reliable stock for the fresh fruit trade.

Cranberry Canners, Inc., sponsors a buying pool for the growers and maintains effective research to find new uses for cranberries.

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[17] Office at Middleboro, Mass.

[18] Office at 90 West Broadway, New York City.

Minot Food Packers, Inc., Hill Brothers Co., Stokely Brothers and Co., Inc., and Pappas Brothers, Gillies and Co. are other concerns that can a lot of cranberries.

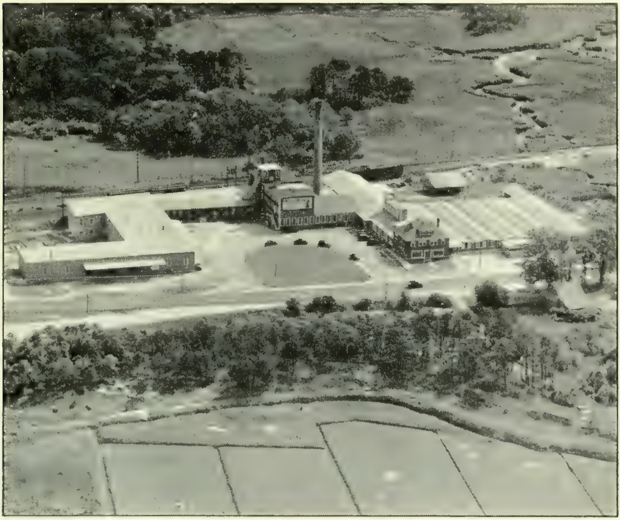

Fig. 40. Cannery at Onset, Mass., one of three operated by Cranberry Canners, Inc.

MACHINERY AND TOOLS

A list of those who serve the cranberry industry and are located in the Cape Cod section is given for the convenience of growers. No specific recommendation for any listed firm or product is intended.

H—makes and repairs power picking machines
M—makes and repairs dusting machines and sorting machinery
N—provides insect nets
P—installs and repairs pumping plants
R—sells and repairs rototillers
S—provides and repairs picking scoops only
T—provides wheelbarrows, picking scoops, and bog tools
X—makes and repairs packing equipment

Maurice Allen, Osterville	R
H. R. Bailey Co., South Carver	P M T X
Beaton's Distributing Agency, Wareham	P, also bog supplies
Bruce & Hubbell Engineering Co., 93 Center St., Brockton	X
F. L. Buckingham, Plymouth	T
Antone Burgo, Pleasant Lake	S
Arthur H. Chandler, Marshfield	S
Henry Guerin, South Middleboro	P
Hayden Cranberry Separator Manufacturing Co., Wareham	P M T X
Mathewson Machine Works, 2 Hancock St., Quincy	H
Jay A. Ward, North Carver	P

Nearly all the spraying machines used by our cranberry growers are made by the following concerns:

John Bean Manufacturing Co., Lansing, Michigan
(Maxim Motor Co., 170 Wareham St., Middleboro, Mass., agent)
Fitzhenry-Guptill Co., 135 First St., Cambridge, Mass.
Frost Insecticide Co., Mill St., Arlington, Mass.
F. E. Myers Co., Ashland, Ohio
(Hayden Cranberry Separator Manufacturing Co., agent)

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AGRICULTURAL EXPERIMENT STATION

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The McIntosh Drop

By Lawrence Southwick

The dropping of fruit before harvest causes considerable financial loss to growers of McIntosh, our leading apple variety. Investigations designed to give a clearer understanding of the problem and to evaluate the possibilities of remedial measures are reported in this bulletin.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

A heavy preharvest drop reduces the value of a crop of apples and tends to nullify the effort that has brought the crop successfully to this stage.

THE McINTOSH DROP

By Lawrence Southwick[1], Research Assistant in Pomology

Introduction

One of the problems in the production of McIntosh apples in Masachusetts is the dropping of fruit just prior to picking maturity. This varietal trait often forces orchardists to harvest crops before the attainment of maximum size, color, and quality. Furthermore, dropping increases in severity through the season of harvest. Even moderate winds and slight jarring of limbs incident to picking operations result in considerably lowering the percentage of fancy hand-picked fruit which a good grower might otherwise expect. Such a loss is serious enough when harvesting is not delayed in waiting for more color development. With the present insistent demand for high color, the grower is tempted to delay picking, and this invariably intensifies the drop problem. Spot picking is an alternative which offers two important advantages: a better average color for the total crop and a lessened fruit drop. Disadvantages are increased inconvenience and cost of harvesting. Another practice which has been developed to some degree of usefulness in recent years is that of early picking followed by sun coloring. The investigations of Hoffman (10) and others have shown that green apples can be sun colored successfully under partial shade. Practical results have been variable. In some instances growers have been quite successful, but in many others results have not been particularly satisfactory because of extra cost, sun scald, mechanical and insect injuries, decreased storage life, and inferior quality. Furthermore, the color often is not bright as in normally ripened fruit.

Extent of the Problem

Not only in Massachusetts but over the entire McIntosh belt, orchardists are concerned with this very definite problem of drop. In Massachusetts, growers have reported dropping of more than 50 percent of the crop in many cases; in New Hampshire, up to 35 percent; in Maine, from 1 to 15 percent; in Connecticut and Rhode Island, from 10 to 30 percent. Other sections report similar results. A general survey indicated that dropping is more severe as the southern limit of the McIntosh belt is approached. This might be expected because of higher mean summer temperatures and the attendant difficulties in the way of good color development. Undoubtedly, McIntosh has been planted south of its best range and in such cases the difficulties in getting the fruit to color properly and to hang on are increased. In many sections the dropping tendency of McIntosh has cost this variety a place on the recommended commercial planting list. In some areas such as New Jersey, McIntosh is being replaced by Lobo, not on the basis of quality but rather because it hangs to the tree considerably better. In fact the present delimitation of McIntosh, which is otherwise widely adaptable, can be attributed largely to its unfavorable reaction to high summer temperatures.

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[1] The author is indebted to Dr. J. K. Shaw for suggesting this study, and assisting in the planning of the experimental work.

Importance of Size Increase of Apples

The importance of delayed abscission is fairly well understood by most growers. Not only is the loss due to bruising lessened and the size, color, and quality enhanced, but the actual bushel yield may be increased. An apple usually continues to increase in size as long as it remains attached to the spur. The data in Table 1 show this relationship.

Table 1—Size and Crop Increase of McIntosh Apples, 1937

(Tree B-7)

Time of Drop	Average Diameters (mm.)		Average Volume in cc.*	Approximate Number of Apples in a Bushel (45 pounds)	Approximate Bushels per Acre (based on 50,000 apples)
	Cross	Length			
Sept. 6-8	64.2	55.0	118.7	172	291
9-11	64.1	55.5	123.1	166	301
12-14	65.7	56.2	127.1	161	311
15-17	66.6	56.7	132.6	154	325
18-20	67.5	57.9	137.3	149	336
21-23	69.3	59.3	149.0	137	365
24-26	69.6	59.1	150.4	136	368
27-29	70.0	59.3	151.6	135	370
30-Oct. 2	71.4	59.5	158.9	130	385
Oct. 3-5	72.2	60.6	165.4	123	406

*$V=4/3 \pi a^2b$ (a=cross radius. b=length radius)

From these figures — and there are many others that show the same trend — it is clear that the apples continued to grow in size into October. The time limit actually is determined not by date but by the arrival of cold weather. The columns giving the computed number of apples per bushel and the approximate yield per acre show the advantage to the grower of extra days and weeks of continued fruit development on the tree. The increase from 291 to 406 bushels per acre means a 40 percent gain in yield. There are few practices which give a better return. It should be pointed out that this result might have been less striking had the full crop remained on the tree. That is, after any drop there may be an exaggerated increase in the growth of the fruits remaining, as a result of increased supplies of nutrients and especially of water. However, it does stand to reason that in most cases a real delay in the normal McIntosh drop would prove very profitable from the standpoint of crop increase. Furthermore, our results at Amherst show that late picking of McIntosh usually results in increased storage life of the fruit. This is in line with recent findings in New Hampshire (23).

Difference in Varieties

Dropping of apples is a natural phenomenon. But it interferes with full color and quality development more seriously with some varieties than with others. Many varieties ripening in late summer and early fall may drop excessively, while some late sorts hang on tenaciously. For example, Williams, Gravenstein, Wealthy, Fameuse, and McIntosh are worse offenders than Cortland, Rome Beauty, Twenty Ounce, Northern Spy, and Golden Delicious. Length and flexibility of pedicel and spur probably have some influence. For example, Golden Delicious has a long pedicel and Rome Beauty a pendulous spur, both of which tend to lessen the strain at the point of attachment of pedicel and spur. McIntosh has a rather short pedicel and a stiff spur which invite disaster during windy periods at harvest time.

The Process of Abscission

Morphologically, abscission is the severing of a modified branch or axis. It may occur at various times from petal fall to harvest. But the nature of the abscission process is not the same for flowers and young fruits as for older fruits. According to observations of Heinicke (8), MacDaniels (15, 16), and McCown (17), in early abscission, secondary cell division forms an abscission layer in or somewhat distal to the abscission zone and separation occurs between cells in the distal half of the abscission layer. But from the time of the completion of the June drop and continuing to harvest, there is definite evidence that cell division does not take place preceding or during abscission of maturing fruits. Rather, the cause of cell separation lies in physiological and chemical changes such as swelling and extension of cell walls and the breakdown of cellulose and pectic compounds. MacDaniels (15) observed various modifications of the normal pedicel in the region of the abscission zone which naturally weaken it in that area, although McCown (17) concluded that the line of abscission does not invariably keep within the zone bounds. Compared with Rome, Spy, and Delicious, the abscission zone in McIntosh is more clearly defined and relatively free from sclerenchyma, fibers, and stone cells, and the constriction is deep, resulting in a small cross-sectional area for support according to MacDaniels (15). No marked structural differences could be found in the abscission zones of fruits from McIntosh trees showing differences in time of fruit dropping, however. McCown (17) observed that pith abscission usually preceded the separation of cortical tissues in McIntosh and Grimes Golden while the reverse was true with Golden Delicious and usually with Rome Beauty and Delicious. The latter procedure allows the woody cylinder to hold the fruit for some time after the separation of the softer tissues. He concluded that this variation in the mode of separation may account in part for the variable severity of drop in different varieties.

Some Apparent Causes of Drop

There has been much fruitful investigation concerning the causes of the shedding of flowers and the abscission of young fruits. Many factors, including fertilization, embryo abortion, and competition have been evaluated. Comparatively little work, however, has been done with late or preharvest drop. Blake[2] suggested that high temperature leading to rapid carbohydrate respiration may be a significant factor in bringing about fruit drop in New Jersey before and during the harvest period. In Rhode Island, Christopher[3] observed variable dropping according to spray materials used, the amount of drop depending on the causticity of the spray. At Amherst it was found that late season defoliation sometimes caused earlier dropping of McIntosh apples. In any one section, there seems to be a negative correlation between altitude and the severity of McIntosh drop. A favorable response to phosphate fertilizer was noted by Harrington[4] in the Bitter Root Valley of Montana. Fertilization with nitrogen alone seemed to cause severe dropping while the addition of phosphorus resulted in "much better sticking qualities." However, there is not sufficient evidence to prove that this is generally true. Increased dropping due to boron deficiency conditions and excessively high lime in the soil has been noted in Canada according to Davis[5] and Mann.[6] Premature fruit drop has been attributed from time to time to undesirable physical characteristics of soil, but in New Hampshire differences in soil structure could not be correlated with the amount of dropping (24).

Effect of Soil Fertility

In 1936, Shaw and Southwick (26) reported evidence of increased dropping on heavily mulched plots where soil nitrates were found in abundance even during the fall and winter months. Later, large amounts of available potassium also were found to be present (27). No mineral fertilizers had been applied to either plot up to 1933 when nitrogen was given to the trees under cultivation. Over a continuous period of sixteen years the mulched trees dropped an average of 27 percent compared with 16 percent for the trees under cultivation (Table 2). The difference between the two values is highly significant, the probability of obtaining such a difference due to chance alone being negligible. The severity of drop increased steadily over this period so that in the last few years from 35 to 50 percent drop was a common occurrence. However, it should be mentioned that despite the higher percentage of drop, actually more bushels of fruit were hand-picked from the mulched trees because of the higher yields.

Another illustration of the effects of fertilizer and soil treatment on dropping has been given in Station Block E, again over a 16-year period. This block consists of seven plots and there are ten 27-year-old McIntosh trees on each plot, the interplanted Baldwins having been removed in 1936. Yield and drop data are given in Table 3 on the basis of 4-year periods. Percentages of drop are also given for the 8-year period from 1930–1937 and are treated statistically.

Sixty-one trees have been used in these records. Approximately one-fourth of the total crop produced over this 16-year period consisted of dropped fruit despite the rather poor yield record. From 1922 to 1929, dropping was not very severe but was more pronounced on the nitrogen plots. Some treatments have been changed since 1929 and during the period 1930–1937 a heavier fertilization

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[2] M. A. Blake. Correspondence, 1937.
[3] E. P. Christopher. Correspondence, 1936.
[4] F. M. Harrington. Correspondence, 1938.
[5] M. B. Davis. Correspondence, 1938.
[6] A. J. Mann. Correspondence, 1938.

TABLE 2 — YIELD, DROP, AND PERCENT DROP BY PERIODS, BLOCK G

Plot	Dates (Inclusive)	Average Annual Tree Yield (lbs.)	Average Annual Tree Drop (lbs.)	Approximate Percent Drop
Cultivated....	1922–1925	298	22	7
	1926–1929	354	58	16
	1930–1933	666	111	17
	1934–1937	910	245	27
	1922–1937			16.0±0.97*
Mulched.....	1922–1925	491	76	15
	1926–1929	709	200—	28
	1930–1933	968	286	30
	1934–1937	1212	486	40
	1922–1937			27.0±1.38*

*Standard error.

program was followed which in general resulted in greatly increased preharvest fruit drop. Four of the plots exhibited significantly higher percentages of drop than the others. These are plot 6, in sod, which had liberal nitrogen applications (300–500 lbs./A) during the entire period plus potassium since 1927; plot 1, in cultivation, which had no fertilizer additions up to 1932 when a complete program was initiated; plot 7, a duplicate of plot 1; and plot 5, in cultivation, which was fertilized liberally with nitrogen since 1927. Of the plots with comparatively low drop, 2 and 4 are in sod fertilized with nitrogen only and 3 is a check plot in cultivation. With regard to plots 2 and 4, it is generally recognized that a good sod utilizes considerable nitrogen thus reducing the amount available to the trees. Plot 3 has never been fertilized. From these data it appears in a general way that as better fertilizing practices were followed, increases in drop resulted. At the same time, there were definite crop increases. Table 4 shows the relationship between yield and drop over the entire 16-year cropping period. The plots are listed in descending order according to the approximate percentage of drop. In comparing the percentage of drop with the yield, it is evident that a correlation exists. Dickson (4) likewise found evidence that severity of dropping was associated with increased yield induced by better cultural conditions.

In order to test the significance of the association between yield and drop in the separate plots, correlation coefficients were derived using individual tree yields (above 50 pounds) from 1927 through 1937. These values also are given in Table 4. The three highest coefficients — for plots 1, 3, and 6 — are significant but rather small, giving coefficients of determination: .28, .22, and .15. Hence not more than 15 to 28 percent of the variance in drop could be attributed to the effect of yield. The other values range below the usual levels of significance. This indicates a variable association between yield and drop within the plots. Data from other plots tend to substantiate this conclusion.

It is interesting to note that the trend of preharvest dropping severity was in a general way similar to that of Block E. Plots 1, 6, and 7 have shown a steadily

TABLE 3—PLOT TREATMENTS WITH YIELD AND DROP DATA BY PERIODS, BLOCK E

Plot	Soil Management	Dates (Inclusive)	Fertilizer Treatment	Average Annual Tree Yield (lbs.)	Percent Drop
Plot 1	Cultivation	1922–25	0	233	10
		1926–29	0	214	13
		1930–33	NPK	495	24
		1934–37	NPK	565	41
		1930–37			29.8±2.17*
Plot 2	Sod	1922–25	N	271	17
		1926–29	N	171	20
		1930–33	N	304	17
		1934–37	N	369	33
		1930–37			23.5±1.51*
Plot 3	Cultivation	1922–25	0	173	15
		1926–29	0	119	12
		1930–33	0	270	16
		1934–37	0	371	33
		1930–37			20.8±1.63*
Plot 4	Sod	1922–25	N	268	19
		1926–29	N	170	20
		1930–33	N	245	16
		1934–37	N	314	25
		1930–37			19.7±1.48*
Plot 5	Cultivation	1922–25	0	197	10
		1926–29	N	257	26
		1930–33	N	415	22
		1934–37	N	375	36
		1930–37			29.4±2.12*
Plot 6	Sod	1922–25	N	349	16
		1926–29	NK	347	19
		1930–33	NK	499	24
		1934–37	NK	548	49
		1930–37			33.2±2.62*
Plot 7	Cultivation	1922–25	0	221	9
		1926–29	0	230	15
		1930–33	NPK	325	16
		1934–37	NPK	476	39
		1930–37			29.2±2.11*

Total yield of all trees on all plots 1922-1937 = 300,703 pounds
Total drop of all trees on all plots 1922-1937 = 74,422 pounds
Percent of total crop that dropped = 24.75 percent

*Standard error.

increasing preharvest drop from period to period (Table 3) with a greater than average increase in the last four years of the study. In the other plots the dropping percentages remained somewhat more constant, with only minor fluctuations until the last period when again a sharp rise occurred. Four possible factors may have had something to do with bringing about this trend: increasing tree age, heavier fertilizer applications, weather conditions more favorable to drop, and variable time of harvesting.

TABLE 4 — TREE YIELDS AND PERCENTAGE DROP BY PLOTS AND CORRELATION BETWEEN YIELD AND DROP WITHIN PLOTS, BLOCK E

Plot	Average Annual Tree Yield (lbs.)	Percent Drop	Correlation Coefficient
6	436	30.7	+.525 ± .112*
1	377	26.5	+.467 ± .083
5	311	25.1	−.097 ± .111
7	313	23.3	+.205 ± .102
2	279	22.6	+.160 ± .105
3	233	22.2	+.389 ± .058
4	249	20.0	−.079 ± .108

*Standard errors.

Further evidence concerning the role of nitrogen follows. Dickson (4) reported that a reduced nitrate supply following a minimum cultivation program was associated with less severe dropping of McIntosh. Hoffman (11) reported increased preharvest drop under conditions where trees in sod could obtain excessive amounts of nitrates during the latter half of the growing season. Nitrogen applications to trees on a good orchard soil over a 4-year period increased both total yield and preharvest drop. The check trees were unfertilized. In one case of differential treatments heavy fertilization with sulfate of ammonia was followed by increased dropping percentage despite the fact that the total yield was below that of the trees lightly nitrated. Southwick (29) found evidence of a correlation between time of drop and amount of spur nitrogen in percentage of dry weight. Here again a high nitrogen condition favored abscission. MacDaniels (16) observed that fruits did not drop as readily from trees of bearing age which had been moved as from normal trees. In such cases it is possible that the pruned and disturbed root systems were unable to obtain the normal requirements of nitrogen, moisture, and other constituents of nutrition. Such plants making slow growth and having a high carbohydrate–nitrogen ratio often produce harder tissues than normal or high-nitrate plants, with a resulting retarding effect on the abscission process. Additional evidence on this point will be cited later.

The author injected individual limbs with several nutrient solutions in the summer of 1939. Nitrogen (in the form of urea) hastened drop. In one case, for instance, the mean date of drop from a nitrogen-injected limb was fully four days earlier than that from similar untreated limbs or limbs injected with non-nitrogenous materials. However, it should be mentioned that in certain cases other materials also increased early dropping, especially when injected in sufficient quantity or concentration to cause visible foliage injury.

Other corroborative evidence can be found in the practical experiences of fruit growers who often report increased drop under conditions of high fertility, especially in relation to nitrogen. On the other hand, less concern with drop is manifest by those growers who operate their orchards on the "hard" side in contrast to being liberal with nitrogen. Scantily fed orchards in tough sod usually show less dropping — and less yield — than orchards in sod highly fertilized, under regular cultivation, or under heavy mulch.

Effect of Girdling

In the summer of 1939, a 15-year-old tree was chosen for a study of the dropping behavior of individual limbs treated in different ways. This tree was carrying a heavy crop and was in a fair state of vigor. Branch treatments and subsequent dropping results are given in Table 5.

TABLE 5 — EFFECT OF LIMB TREATMENTS ON SUBSEQUENT DROPPING (1939)

Treatment	Date of Treatment	Total Number of Apples	Percent of Apples Still Hanging After October 4
1. Girdled by 3 knife cuts	Sept. 7	54	43
2. Girdled by removing strip of bark	Sept. 7	50	39
3. Xylem partly destroyed by boring	Sept. 7	46	37
4. Girdled by removing strip of bark	Aug. 1	157	25
5. Check		600	19

All of the treatments had a retarding influence on fruit drop. Girdling was more effective when done in September than a month earlier, even though the August girdle did not heal over. It should be pointed out here that such treatments, though useful from an experimental standpoint, are drastic and of course impractical. Murneek (21, 22) has shown that apple fruit set can be increased by branch ringing and evidently the effect is produced largely by the alteration of the carbohydrate supplies. The girdling was done at the time of full bloom. Hodgson (9) found that girdling reduced fruit drop in the persimmon. He observed that excessive dropping was usually associated with high tree vigor.

The single-year data in Table 5 are rather limited but the differences in the drop of the variously treated branches are quite pronounced. It would seem that girdling should reduce the upward passage of nitrogen and other nutrients as well as the downward movement of carbohydrates. Perhaps both of these effects could influence the normal initiation and progress of fruit abscission. With the role of nitrogen in its relation to drop more or less evaluated (above), it would seem that nitrogen supply is probably the important factor.

Effect of Stock

Block D is a 10-year-old clonal stock planting of McIntosh and Wealthy. Table 6 gives the yield and drop data for some of the McIntosh trees for the period 1934-1937 inclusive.

TABLE 6 — BLOCK D, McINTOSH YIELDS AND DROPS BY STOCKS (1934-1937)

Stock	Class	Number of Trees	Average Annual Tree Yield (lbs.)	Percent Drop
M. 16	vigorous	13	218	47.2±2.68*
Seedling	vigorous	14	163	42.6±3.00
M. 4	semi-dwarf	2	164	40.0 —
McIntosh	vigorous	14	176	39.5±3.35
M. 1	semi-dwarf	13	145	32.5±3.58
M. 5	semi-dwarf	3	93	32.0 —
M. 15	vigorous	14	83	30.4±3.78
M. 6	semi-dwarf	3	72	30.0 —
M. 13	vigorous	13	108	29.0±3.22
M. 10	vigorous	13	164	25.5±2.89
M. 12	vigorous	14	143	23.0±2.09

*Standard errors.

The fruit drop varied from 47.2 percent to 23 percent with the different stocks. These figures are based only on 50-pound yields or above and the populations are relatively small. It seems noteworthy that such young trees have been beset by so much preharvest dropping of fruit. However, the trees have grown rather vigorously under a cultivation-cover-crop system. Perhaps the outstanding feature of these data is the variation in dropping severity among the different stocks without particular regard to their dwarfing effects on the scion. As these stocks, however, are not randomized in the block, accurate interpretation is difficult. Nevertheless, some of the variations in dropping behavior do seem to refer to stock influence. As the trees grow older and yields increase, the extent of the differences may be reduced. As was the case with Block E, there was again some association between yield and drop. The most notable exceptions seem to be with trees on M.12 and M.10, which yielded fairly well yet lost relatively little fruit from preharvest dropping.

Influence of Seeds

The importance of living embryos and seed development in connection with the set and early growth of apples has been observed in many investigations (1, 2, 3, 7, 8, 12, 13, 14, 19, 20, 25, et al.). In general, with apples the presence of seeds is intimately associated with fruit development. The ovarian tissues and the fleshy portion of the apple develop along with the enclosed ovules, and important differences in this development are often associated with varying seed number, growth, and distribution. That seed influence should be maintained to some degree throughout the growing season seems plausible even though the development of seeds in the early life of the fruit is probably of greater significance than their presence later on. It is well established that fruit symmetry and size are often affected by seed content and distribution. The author (28) has published some data relative to the possible part played by seeds in delaying preharvest McIntosh drop. Table 7 summarizes this and supplementary data.

Table 7 — McIntosh Drop Data for Three Years from Individual Trees in Three Orchards

Tree	Number of Drops Studied	Mean Number of Seeds per Fruit	Coefficient of Correlation, Seed Number and Date of Drop
		1936	
B-6 Block P	933	8.0 ± .10*	+.348 ± .028*
B-7 "	289	7.2 ± .23	+.542 ± .043
J-10 Block E	347	6.2 ± .13	+.318 ± .049
J-12 "	369	7.9 ± .14	+.279 ± .047
		1937	
G-18 Block D	1937	9.3 ± .08	+.302 ± .027
F-25 "	1433	9.5 ± .08	+.264 ± .023
J-10 Block E	2630	6.2 ± .06	+.270 ± .018
		1939	
C-10 Block D	1963	8.7 ± .09	+.444 + .018
C-12 "	1349	7.5 ± .12	+.540 ± .019
C-14 "	1302	7.4 ± .12	+.419 ± .023
C-16 "	1120	6.6 ± .10	+.332 ± .027
G-10 "	1437	7.9 ± .12	+.408 ± .016
G-12 "	1185	8.1 ± .14	+.610 ± .012
H- 9 "	1670	7.6 ± .12	+.572 ± .016
H-11 "	1217	8.3 ± .13	+.509 ± .021

*Standard errors.

The apples were numbered or otherwise designated with India ink in August and natural dropping was allowed to go to completion. The drops were gathered daily and subsequently the seed content of each was determined. Certain individual limbs only were used in 1936 with B-7, J-10 and J-12. Otherwise the entire crop was included in the determinations.

The correlation between date of drop and seed content is evident. The coefficient values are statistically significant, although they signify only moderate degrees of association for the most part. This is brought about by the inevitable exceptions. Fruits with very few seeds sometimes hang on remarkably well and vice versa. This would indicate that the influence of seeds or of other factors is by no means constant. The seed influence was in most cases more definite in 1939 than in the other years. It should be pointed out that some apples must have been jarred by other falling apples and perhaps forced prematurely from their spurs. However, this factor was not considered sufficiently serious to alter appreciably the coefficient values

In the table above, the average number of seeds per apple varied from 6.2 to 9.5 depending largely on the tree and perhaps somewhat on the year. Normally, fully developed seeds vary in number from none to 20 in McIntosh apples. However, the author found two apples which contained more than 20 seeds. To show just what a correlation of +.610 means (Table 7 — G-12, 1939) in actual seed numbers of apples dropping at different times, the following figures are illustrative. In the case chosen, the apples which dropped before September 21 contained on the average 2.7 seeds; during September 25 to 28, 4.0 seeds; on October 4, 8.5 seeds; and on October 12, 11 seeds. The drop in 1939 came later than usual. For instance, in 1937 with another tree in the same block, over 50 percent of the crop had fallen by September 15. The seed contents of the apples dropping at weekly intervals were as follows: September 2, 7.5 seeds; September 9, 8.3 seeds; September 16, 10.6 seeds; September 23, 11.8 seeds. The correlation here amounted to only +.302 (Table 7 — G-18, 1937). Mean drop dates among individual trees have been found to vary as much as 20 days in one locality. But the seed influence is manifest, nevertheless, and the apples with the most seeds tend to hang on the longest.

Whether seed content is merely an associated factor or whether it actually plays a causative role in determining time of drop is difficult to prove. The significance of embryo and seed development in the life of young fruits is quite well founded. It would seem logical to suppose that the association found to exist in maturing fruits is just as definitely one of cause and effect. It seems plausible that the presence of many viable seeds tends to cause the build-up of stronger tissues in the pedicel and helps to insure more adequate and constant supplies of nutrients and moisture. Perhaps the beneficial effect on "sticking" of apples just prior to and during the harvest period is related to the lowering of the ratio of nitrates to carbohydrates due to the increased utilization of available nitrates. The author studied starved trees in which dropping was retarded in a similar way to that described by MacDaniels (16) for weak trees. There was no significant correlation between seed content and time of drop with these abnormal trees. This indicates again that the value of seeds in retarding drop may be overshadowed by other physiological factors. The author (29) found some evidence that larger spurs, measured by weight, favorably influenced the hanging ability of apples at harvest time. As measured by cluster base diameter also, in a single correlation, a positive coefficient of low value was obtained. In two other cases, no association could be detected. The larger spurs (in a single experiment) likewise contained lower percentages of nitrogen which in itself may have been the significant factor (29). Heinicke (7) found spur size to exert a similar influence with young fruits. Often, large spurs compensated for low seed values in assisting fruits to stick on.

An analysis of the dropping behavior of individual limbs of a tree revealed little departure from the normal behavior of the tree as a whole. However, the seed data revealed that the apples on the low spreading branches contained more seeds than the apples on the vigorously growing upright leaders. This indicated a possible difference in the ability of limbs to hold apples. Hoffman (11) observed that drop is heaviest in the lower half of a tree as the result of more shade.

Influence of Length of Stem

Stem length measurements were taken on some 6,000 drops at the time of seed count in 1937. The stems varied from 5 to 26 millimeters in length. With the crop of one of the three trees a low but significant correlation (+.136 ± .016) between stem length and time of drop was obtained. Considering that very low negative coefficients were obtained with the other trees, it appears that length of stem in itself played a minor role in fruit drop. It has already been suggested that a short stem might enhance the chances for early dropping for the reason that a comparatively greater strain is placed at the point of contact of the stem and spur than is the case when the stem is long and pendulous. This factor probably plays a significant role in the behavior of different varieties. But it is doubtful if stem length is important in regard to the apples on a single tree, although with young fruits Heinicke (7) found that those with short stems had an advantage.

Chemical Composition

Analyses were made of apples which dropped from two trees at intervals of 10 days (Table 8).

TABLE 8 — ANALYSES OF APPLES THAT DROPPED FROM TWO TREES (G-18 AND F-25) AT TEN-DAY INTERVALS, 1937
(Computed to Dry Matter Basis)

	G-18*			F-25*		
	Sept. 3	Sept. 13	Sept. 23	Sept. 3	Sept. 13	Sept. 23
Dry Matter	100	100	100	100	100	100
Ash	2.429	2.220	1.954	2.439	2.324	2.161
P_2O_5	.135	.099	.069	.227	.214	.209
K_2O	.941	.911	.795	1.166	1.060	1.007
Na_2O	.137	.149	.149	.077	.101	.114
CaO	.134	.140	.154	.125	.111	.129
MgO	.112	.107	.104	.108	.093	.107
Total N	.378	.399	.342	.411	.386	.325

*G-18 samples taken from cold storage in November.
F-25 samples taken from cold storage in January.

The moisture contents approximated 88 to 89 percent leaving 11 to 12 percent of the fruit composition as dry weight. The ash percentages of the apples evidently decreased as the season advanced, indicating relative increases in total carbohydrates. Phosphorus and potassium showed decreases while sodium and possibly calcium tended to increase to a slight degree. Such changes could not be considered particularly at variance with those attending normal fruit development. Hence, no clear indication was found that total ash or its constituents markedly affected dropping. The decrease in total nitrogen may have some significance, especially in consideration of the previous discussion of the relationship of nitrogen to drop.

Effect of Strain

In recent years there has developed considerable grower reaction in regard to strains of McIntosh as well as of other varieties. In general, the opinion is favorable to "red bud sports" because of the color advantage. Furthermore, the idea prevails that the blushed type of McIntosh does not drop as much as the striped type. As yet adequate data are lacking to clear up this point. However, Dickson (4) reported practically the same percentage drops from blushed and striped types over a period of years. He concluded that nutritional factors rather than mutation may account for many of the "so-called non-dropping 'sports' of McIntosh." It is possible that certain soil factors influence dropping and that these same factors favor light color which in turn would bring striping to attention. In Pennsylvania, Clarke[7] has found evidence of variable dropping in different strains but light dropping was not necessarily limited to the blushed type. Probably the blush or solid red color can be associated with the non-dropping faculty, but evidently this is not necessarily the case. Investigations on this problem are under way at Amherst and it is hoped that definite progress can be made in this field.

Influence of Weather Conditions

Undoubtedly, daily weather conditions influence daily dropping of apples at harvest. Wind plays an indirect or secondary role in shortening the time that an apple can remain attached after the initiation of abscission processes. Further-. more, wind if severe enough produces unnatural drop by causing separation without regard to normal abscission.

Dropping records have been correlated with the various factors of weather with somewhat uncertain results. Thus it is difficult to evaluate weather conditions even though the significance of their influence is recognized. Under Amherst conditions there has appeared some association between dropping and temperature. For instance, in 1937, dropping was severe following the 24th and 25th days of September when high maximum temperatures were prevalent. It is also significant that during that particular period, the total wind movement was small. The records yield additional evidence on this point but the effects often may be masked by other factors. It has been mentioned previously that a summer temperature mean too high for a variety often causes severe early droping. This is evidenced with McIntosh in the more southern sections of its range. Blake[8] suggested that a drop following a period of high temperature may be due to rapid carbohydrate respiration, especially on actively vegetative trees. Sometimes dropping has been more severe following a wet than a dry season. If the carbohydrate–nitrogen ratio is a significant factor, as intimated previously, there should be an association here. Hoffman (11) suggests that with equivalent nitrates available for growth, carbohydrate accumulation is less in a wet year. Undoubtedly, then, the actual internal condition or perhaps growth status of a tree in relation to its environment becomes an important focal point in the consideration of the droping phenomenon just prior to and during the harvest period. State of fruit maturity at any particular time is the net result of the tree–environment relationship and hence is associated closely with drop. Since the factors of weather are largely beyond our control the value of ascertaining their separate and combined effects on fruit drop lies in subsequently adapting cultural practices to better fit the natural scheme of things.

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[7] W. S. Clarke, Jr. Corespondence, 1938 and 1939.

[8] M. A. Blake. Correspondence, 1936.

Influence of Spot Picking

The place of spot picking should be mentioned at this point. Many growers in Massachusetts are using this harvesting scheme and report much less loss from dropping as well as a marked increase in color of the crop as a whole. Fruit maturity is a factor in apple abscission. But further than this, there is some indication that a partial harvesting of a crop results in a better chance for the remainder to "stick on." On the other hand, many of the apples which are left after a spot picking probably would not have dropped much sooner without the stimulus of partial crop removal. Be that as it may, harvesting McIntosh two or three times according to color development is a sensible procedure, provided the picking cost per bushel is not raised unduly.

Influence of Chemicals

The effectiveness of several chemical compounds in delaying and preventing harvest drop of apples has recently been demonstrated. Following the discovery that abscission of floral structures, stems, and petioles was delayed on cuttings treated with certain hormone compounds, Gardner and others (5) conceived the idea of utilizing these substances to prevent the normal dropping of fruits just prior to and during the harvest period. They found that many of the commercial so-called plant growth substances have some effect in delaying abscission. Naphthalenacetic acid and naphthaleneacetamide proved to be more effective than certain esters or the indole compounds. Further experimental results have checked and extended the original findings (6, 6a). The chemicals, applied thoroughly in dilute sprays (1 to 10 parts per million of water) evidently delay the abscission processes for periods varying from one to three weeks depending on the variety and certain other factors such as temperature. Gardner reported marked response to hormone sprays with more than twenty varieties including McIntosh. In contrast with other varieties the effect of the sprays on McIntosh was of rather short duration, usually 8 or 9 days. First appreciable effects were noted 24 to 48 hours after application. Concentrations as low as .0001 percent (1 part per million) were effective, although the higher concentrations up to .001 percent gave better control of dropping. Preliminary experiments (1939) in the Experiment Station orchards at Massachusetts State College with a .00025 percent solution of alpha naphthylacetamide gave positive results in one McIntosh block, but inconsistent results in another block. McCown and Burkholder (18) obtained no significant effect of a spray containing .0001 percent of a naphthalene acetic acid with three varieties. Murneek (22) reported good results with .0005 and .001 percent sprays of both substances.

Gardner (6) found that best results followed the application of sprays to the region of the abscission zone. Spraying the calyx end of Delicious resulted in some delay of drop but application to the zone of attachment of stem and spur was far more effective. Since fruits not hit by the spray probably are not influenced, the necessity for thorough, drenching sprays is evident. Leaf coverage was not found to be particularly important. After the effect wears off, fruit drop may be sudden and severe. However, an additional spray or sprays will extend the effective period. Repeated sprays at short intervals have been known to cause such tight "sticking" that picking became a laborious task.

The usefulness of hormone sprays in certain circumstances is unquestioned. With McIntosh, this method of drop control should be given particular consideration for reasons discussed elsewhere in this bulletin. However, this new development is in the experimental stage. Further investigations and trials should give a more complete understanding of its possibilities. The best techniques of application, the most economically effective ranges of dilution, the proper utilization of proprietary substances, the ultimate effects on the tree and on the fruit, the dependability of the method under variable environmental conditions, the particular conditions, from an economic standpoint, warranting the extra expense, and many other considerations are all yet to be fully developed. Trials by growers are recommended and either the pure chemicals or commercial preparations should be satisfactory.

Summary and Conclusions

The dropping of McIntosh apples just prior to and during the usual harvest period is a definite fault of the variety and is recognized as a serious problem among commercial growers. Many other varieties have the same fault in greater or lesser degree.

The severity of the problem has brought about certain practices designed to decrease losses. Spot picking and sun coloring have been utilized with variable degrees of success.

A reasonable continued growth of McIntosh apples gives increased yields and better fruit condition and emphasizes the practical value of a delayed fruit drop.

The abscission process is characterized by a chemical dissolution of cell walls and separation of tissues rather than by cell division as in abscission of blossoms and young fruits.

The significance of the nitrogen relationship is evident from several angles. Dropping was more severe under cultural conditions which made nitrates plentifully available, particularly late in the season. Heavy mulching, organic or mineral nitrogen applications, late cultivation, and limb injections of nitrogen tended to increase the percentage drop of fruit. On the other hand, a low level of fertility, sod culture, limited cultivation, low tree vigor, and late summer girdling tended to delay the initiation of abscission processes. In many cases, dropping was found to increase with increasing yields. Larger crops in well-fertilized orchards often more than compensate for the heavier drop.

In a planting of McIntosh on clonal stocks, severity of drop seemed to be related to the different stocks but not necessarily according to their vigor.

Seed number was positively correlated with date of drop of apples from individual trees in three years. Number of seeds per apple and mean drop dates varied among the different trees, but seed influence was practically always manifest; and on any particular tree, the apples with many seeds tended to hang longer than those with fewer seeds.

Length of stems of apples was not an important factor in determining the time of drop of McIntosh.

No clear indication was found of any relationship between mineral content and preharvest drop.

The effect of strain is not settled. It is probable that certain strains do not drop as badly as others. There is some indication, however, that the dropping tendency is not necessarily associated with a particular type of fruit color.

The importance of weather conditions was evident but the proper evaluation of all of the various factors was not possible. There was evidence of the significance of high summer means, short periods of high temperatures late in the season, and wet seasons in increasing drop.

The use of hormone sprays to prevent drop at harvest has met with success in some preliminary trials. Since this development is definitely in the experimental stage, however, many details need careful investigation and checking. A sound evaluation of the method should be forthcoming in the near future.

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Foods and Public Health

By James E. Fuller

The wholesomeness of food is of vital concern to the public. It is the aim here to bring together available information regarding the part played by food in the spread of bacterial diseases.

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FOODS AND PUBLIC HEALTH

By James E. Fuller, Research Professor of Bacteriology

In recent years the American people have been made "food conscious" as they never were before. We are being bombarded constantly with food propaganda by radio, newspapers, and magazines. Most of this publicity is intended to promote sales, and the "health information" that is thus placed before the public is frequently misleading and undependable (1). There is, however, a considerable amount of legitimate publicity by authorities who are sincerely interested in promoting public health by improving the nutrition of the people. Not much of this legitimate health propaganda, however, is concerned with the part foods play in spreading infectious diseases.

An infectious disease is caused by a microscopic germ, frequently some kind of bacteria, that may be passed from person to person by direct contact, or through some intermediate agent such as water or milk. An example of direct contact is the spread of the common "cold" by the spray expelled from the mouth or nose of one who is ill, when he coughs or sneezes. Typhoid fever, on the other hand, is spread from person to person by an intermediate agent, usually water or milk, which becomes contaminated from the excreta of persons who have the disease, or have had it, and those who drink the contaminated water or milk are likely to contract typhoid fever. Most of the diseases that infect the digestive tract of man are spread by something that he eats or drinks, while many of the diseases of the respiratory tract may be spread either by direct contact or through food and drink. There are other ways of spreading infectious diseases. Mosquitoes, for instance, spread yellow fever and malaria. This bulletin, however, is concerned only with diseases spread by food, including milk.

The public, generally, is not very well informed as to the importance of foods in the spreading of infectious diseases. Most people know that typhoid fever can be contracted from milk or water, and tuberculosis from milk. They know, also, that the eating of spoiled foods, especially meat, may result in an attack of an intestinal ailment commonly called "ptomaine poisoning". Public knowledge of food-borne diseases does not go much further than these examples. It may be well to point out here that it is incorrect to say that foods cause infectious diseases. Foods can cause disease only if they themselves are poisonous, or if they lack necessary nutritive substances such as vitamins; and in either instance, the diseases so caused are not infectious. Germs alone can cause infectious diseases, and foods act only as agents for carrying the germs and spreading the diseases.

The statements made in the pages that follow are not intended to frighten anyone, and there is no reason why they should. It hardly needs to be said that one is in a much better position to protect himself if he knows where his enemies are to be found and how they behave. It should be a relatively simple matter for people, most of them at least, to avoid food-borne infections by the exercise of intelligent care in selecting food in the market and handling it in the home.

The writer claims no originality for any statements made in this bulletin, except for one or two personal experiences used for illustration. The information presented is taken purposely from the writings of recognized authorities in the scientific fields represented. A list of references will be found at the end of the bulletin for the use of readers who may want to verify statements made, or to read further about any of the topics discussed.

DISEASES SPREAD BY MILK

Of all foods, market milk is perhaps the most common carrier of infectious diseases. The importance of this fact becomes more apparent when one stops to think that milk is the essential food of young children, and is a substantial item in the diet of most people throughout their lives. Tuberculosis, typhoid fever, scarlet fever, septic sore throat, and undulant fever are diseases commonly spread by milk. There are others less important or less common that will not be discussed in this bulletin.

Tuberculosis

Cattle easily become infected with tuberculosis, and it is highly probable that many cases of tuberculosis, especially in children, could be attributed to the milk of tuberculous cows (2). Tuberculosis in children frequently infects parts of the body other than the lungs. The infection is often found in glands, a fact which strengthens the opinion that milk may be a source of the disease. Many medical authorities believe that the germs can pass from the intestines into the glands, by way of the lymphatic circulation, and eventually reach the lungs. Tuberculosis develops slowly in the body, so naturally there are no epidemics such as occur with typhoid fever, septic sore throat, diphtheria, and scarlet fever.

It is not difficult to detect tuberculosis in dairy herds. The presence of the germs in milk can be determined by laboratory tests, but the most usual method is to apply the tuberculin test to cattle. The nature of this test will not be taken up in this bulletin. All dairy farmers are familiar with it. The use of the tuberculin test makes it possible to free dairy herds of cattle that have tuberculosis. The result is of double value—it benefits both the dairy farmer and the consuming public. Since the beginning of the century, tuberculin-testing programs over the United States have produced a marked improvement in the health of dairy herds and have decreased measurably the financial loss from the disposal of tuberculous animals. Over the same period, the prevalence of human tuberculosis, and the accompanying death rate from the disease, have decreased markedly in this country; and undoubtedly a considerable part of the credit for this improvement must be given to the eradication of tuberculosis from dairy herds. Goats are not often infected with tuberculosis, and their milk is relatively safe in that respect. This appears to be due to the way in which the animals are handled, rather than to their immunity to the disease, because goats can be infected with tuberculosis (3).

Typhoid Fever

Typhoid fever is a disease that is likely to break out in explosive epidemics, although isolated cases frequently occur. Epidemics of the disease usually are traced to water supplies or to milk supplies. Water sanitation is a large subject in itself, and should be treated separately, so only milk-borne typhoid will be considered here. Many epidemics are on record ranging all the way from a few cases with few or no deaths, to hundreds of cases with many deaths.

An instance was reported in California (4) in which milk from a dairy farm was sold raw in one town, and pasteurized milk from the same farm was sold in another town close by. In the first town a number of cases of typhoid fever occurred among about five hundred persons using the milk, while in the second town no cases occurred among about six thousand consumers. Investigation of the dairy farm showed that the head milker had been taken ill with typhoid fever shortly before the epidemc occurred.

Two milk-borne epidemics of typhoid fever in New Jersey (4), which occurred about a year apart, were traced to one carrier. The first epidemic included seventy-two cases, and a carrier was detected among the workers in the dairy which supplied the suspected milk. A year later an epidemic of thirty cases was reported from another community, and when the farm which supplied the suspected milk was investigated, the same carrier was found to be working as a milker and under an assumed name.

An extensive epidemic of typhoid fever occurred in Montreal in 1927 (2), which lasted from March 1 into July. Evidence collected at the time (5) indicated that milk was the source of infection, but later study of the evidence (6) seems to indicate that water may have been the source. This epidemic, of 5,014 cases with 488 deaths, was one of the most extensive on record.

In Massachusetts (7), from 1921 to 1925, there were 3,390 cases of typhoid fever reported, of which 228 (6.7 percent) were from milk; and from 1926 to 1929, there were 1,635 cases reported, of which 135 (8.3 percent) were milk-borne. Dairy products other than milk can spread typhoid fever. Epidemics have been reported from butter, cream, ice cream, and cheese (4).

Typhoid fever germs get into milk and milk products from human sources, and not from cows. One of the epidemics just described was traced to a worker coming down with the disease, and the other to a carrier. All persons who have typhoid fever continue to excrete typhoid bacteria for several weeks, or even months, after recovery, and thus become "carriers". It happens occasionally that the bacteria invade the human gall bladder, where they thrive on the bile. In such instances, the persons concerned become permanent carriers, and eliminate the bacteria more or less constantly from the intestines. Carriers are a constant menace to the public as sources of typhoid fever, and are especially dangerous if they have anything to do with food supplies. Surgical removal of the gall bladder is the most effective treatment for chronic carriers.

Perhaps the most notorious carrier in medical history was Mary Mallon, a cook, who was known as Typhoid Mary because of the typhoid fever that she spread wherever she went. She was a cook in and around New York City, and was known to have infected more than fifty people in families she worked for, over a period of several years. She was suspected also of being the source of a water-borne epidemic of over 1,300 cases of typhoid fever in Ithaca, N. Y., in 1903. She died in November, 1938, after having been virtually a prisoner of the New York City health authorities for thirty-one years because she refused to submit to treatment that would have rid her of the germs. Typhoid Mary did not handle milk supplies, but the results can be imagined if she had.

Carriers can be detected by simple laboratory tests, but the only safe way to handle them is to require that they submit to treatment to clear up the condition, or else to put them under quarantine. The instance was cited above of a milker who infected one milk supply, and later obtained employment under an assumed name at another dairy farm and infected that milk supply. Typhoid Mary also assumed other names as she worked in different homes.

Improved sanitation, including careful public supervision of water and milk supplies, has greatly reduced the number of typhoid fever cases over most of the United States, and especially in New England. Fewer cases mean fewer carriers, and consequently less danger of infected food and milk; but there is still sufficient risk to justify the consumer being very careful of the cleanliness of the milk he buys for his family.

Scarlet Fever

Scarlet fever is contracted from infected milk more often than the public realizes. In a publication from the Massachusetts State Department of Public Health (7) there is a table which lists three such epidemics: one of 15 cases in Pembroke and Marshfield in 1928, one of 15 cases in Framingham in 1929, and one of 127 cases in Plymouth in 1929. Eighty-seven milk-borne epidemics were reported in the United States between 1893 and 1928 (2). An epidemic in Boston and neighboring communities (4) in 1907 illustrates the way in which milk can spread scarlet fever and other epidemic diseases.

The epidemic included 717 cases, of which 486 (68 percent) occurred within six days. More than 80 percent of the cases in each community were in families supplied with milk by a certain dealer. The cases were among customers who purchased bottled milk, and none of the milk sold wholesale appeared to be infected. Investigation showed that an employee in the bottling plant had had an illness that was strongly suggestive of scarlet fever, and cases of scarlet fever existed in the families of other employees.

Milk-borne epidemics of scarlet fever come from human sources. So far as is known, cows do not have the disease (2). It has been suspected that cows afflicted with streptococcus mastitis sometimes liberate germs into their milk that may produce a disease resembling scarlet fever in man, but there is no definite proof; and even if there were, it would still be possible that the cows' udders had been infected from persons carrying the germs. It is not as easy to detect carriers of scarlet fever germs as it is to detect typhoid carriers. An instance in the writer's experience illustrates this point. In one of the larger cities in Colorado there was a dairy run by a wealthy man, as a hobby. The dairy plant, herd, and equipment were as nearly perfect as money and intelligent management could make them, and the utmost care was taken to produce milk of unusually excellent quality. Because of the demand at the time for raw milk, the whole product of the farm was sold as such to customers who could afford to pay for high-quality certified milk. In spite of all the care, a scarlet-fever epidemic occurred among the customers of this dairy, and investigation disclosed that one of the milkers had had scarlet fever not long before he started to work at the farm. He thought that he had completely recovered, and he appeared to be healthy; but he very probably was the source of the infection.

Instances of scarlet fever infection from dairy products other than milk do not appear to be as numerous as with typhoid fever, but outbreaks have been traced to ice cream. An outbreak was reported (2) from Flint, Michigan, in 1924, which included 41 cases and extended over 7 days. The ice cream was infected by the maker who had had a mild case of scarlet fever.

Septic Sore Throat

Septic sore throat, known also as epidemic sore throat, is a milk-borne disease that has become a significant public health problem in relatively recent years. Epidemics traceable to milk have been observed in England since 1875, but the first carefully observed epidemic in this country occurred in Boston in 1911 (8). Since that time, a number of epidemics have been studied, and a streptococcus has been described as the responsible germ. Some authorities believe that one specific species of streptococcus causes the epidemic disease, while others think that several species of related streptococci may be able to set up practically identical disease conditions.

It is probable that septic sore throat is always of human origin (2), coming from a case or a carrier. Attempts have been made to trace the disease to cows afflicted with mastitis, but the prevailing opinion is that there is no relationship between the two diseases. It is true that the streptococcus has been found in milk freshly drawn from cows, but available evidence seems to indicate that such cows have been infected from human source.

For the years 1926 through 1929, there were 1,772 cases of septic sore throat reported in Massachusetts (7). Of these, 1,034 (58.3 percent) were traced to milk supplies. In July, 1928, a very severe explosive epidemic occurred in a small town in Western Massachusetts (9). There were between 925 and 975 cases, and 48 known deaths. A majority of the cases were traced to one milk dealer who bought milk from several dairies, and sold it all as raw milk. A cow in one of the herds was found to have a streptococcus infection of the udder, and one of the milkers and several members of his family had been ill with an infection that may have been septic sore throat. The evidence incriminating either the cow or the milker was only circumstantial, but the epidemic remains one of the most explosive and most severe so far recorded.

Undulant Fever

Undulant fever in man is caused by a species of bacteria that causes contagious abortion in cattle. Malta fever, a disease contracted from goats' milk, has been known in Europe for a good many years, and it was shown in 1918 (10) that the germ causing contagious abortion in cattle is closely related to the germ of Malta fever. This suggested the possibility that a disease occurring in the United States, and recognized as a form of Malta fever, might be caused by the germ of contagious abortion. This belief was strengthened by a succession of experiments, and in 1924 the first proven case of what is now known as undulant fever was reported (8). Even though the disease has been recognized only recently, it probably has been prevalent for many years. This disease comes from infected cattle, not from humans, and is spread by milk. While the disease is contracted principally from milk, those who handle the meat or carcasses of diseased animals may become infected.

Undulant fever gets its name from the nature of the illness in man. The patient suffers from intermittent spells of fever and other symptoms. He may feel quite well between attacks, and think that he has recovered, only to suffer a relapse. This may go on for weeks, with the patient up and down. In its early fever stage the disease may be mistaken for typhoid fever, and no doubt many such diagnoses are made. Later, pains may develop in joints and muscles, and be attributed to rheumatic fever or arthritis. Sometimes there are intestinal symptoms that may lead to a mistaken diagnosis of appendicitis, and useless operation may follow. The death rate from undulant fever is low, but the sufferers are likely to be disabled for so long a time that the disease is economically important.

There is a blood test by which contagious abortion in cattle can be detected, and many states have programs for the systematic testing of dairy herds and the elimination of infected animals. Excellent results have been reported, comparable with those achieved in the eradication of tuberculosis.

In addition to those described above, other diseases, particularly of the intestinal tract, may be spread by milk. Among these diseases are bacillary dysentery, paratyphoid fever (a mild disease resembling typhoid fever), and "summer complaint" of young children. These diseases are from human sources, and the contamination of milk takes place in much the same way as that described for typhoid fever.

Preventive Measures

How may the public be protected from the spread of the diseases described above? Public health authorities in each city or town, as well as state health boards, should, and usually do, exercise control of the sanitation of dairy farms and milk depots. This includes, of course, inspection of employees in these places. Then there are the cow-testing programs for detection of tuberculosis and contagious abortion already referred to. The consumer must take additional precautions to see that he gets a safe milk. If he wants raw milk, he should be certain that the milk he buys is produced and handled with the utmost care and cleanliness. If he cannot get satisfactory information about the dairy he patronizes, he had better buy pasteurized milk.

Arguments for or against pasteurized milk are not within the scope of this bulletin, but a brief statement is not out of order. In the first place, properly pasteurized milk is safe milk. Public health authorities state (2) that milk-borne typhoid fever is always traceable to raw milk. There is no instance on record of an epidemic from a properly pasteurized milk supply. An equally emphatic statement is made (2) concerning all milk-borne diseases.

One of the arguments against pasteurization is that it destroys certain nutritive properties of the milk, especially vitamins. However, if there is any question about the sanitary quality of a milk supply, one can well afford to buy pasteurized milk and depend upon other foods for vitamins. An extensive survey made by the United States Public Health

Service (12, 13) indicates that heated milk is as satisfactory as raw milk as a food for children. The report points out the fact that after the first few weeks of life, or the first few months at most, children receive supplementary feeding by which any vitamins lacking in the milk can be supplied. It is not the intent of this bulletin to discourage the use of raw milk if its sanitary quality can be guaranteed; but if there is any doubt, the consumer should prefer the safety of properly pasteurized milk, which is more generally obtainable than is dependably safe raw milk.

FOOD POISONING

Every one is familiar with those acute attacks of intestinal illness commonly called "ptomaine poisoning." The attacks are characterized by sudden onset, severe intestinal pain, diarrhea, vomiting, and fever. Not all of these symptoms are necessarily present in every case. One may not have vomiting or fever, but the pain and diarrhea generally occur. The ailment is usually of short duration, not more than five or six days at the most. Recovery is usually rapid, and the ailment seldom results in death.

Authorities know now that these attacks are caused by bacteria in certain foods, but for many years it was thought that they were caused by poisons, called ptomaines, that had been produced in foods as the result of the bacterial decomposition of proteins.

Ptomaine Poisoning

The old concept of ptomaine poisoning was described in 1912 in a journal article by an able scientist, LeFevre (14). Even then the ailment was called food poisoning, but ptomaines were thought to be the direct cause of the poisoning, with bacteria only indirectly involved. LeFevre stated that ptomaines are purely chemical bodies formed in protein substances during the process of putrefaction. Some of them are poisons, but they are different from bacterial toxins which are formed within bacterial cells. At the time LeFevre's article was written, about sixty ptomaines had been isolated and studied, and about one-half of them were thought to be poisonous. They represented a wide range of chemical compounds, not too closely related in many instances. The article then proceeded with a discussion of the nature of the ptomaines, and gave a classification of them.

LeFevre's description of the way in which ptomaines are formed agrees essentially with present-day opinion, and it is possible that bacterial decomposition of foods may produce ptomaines that could be poisonous if they were to be eaten in sufficient quantity. However, long before such a quantity of ptomaines could be produced in any food, it would be so badly decomposed that no civilized person would eat it under normal circumstances.

The present scientific concept of the subject of ptomaine poisoning is expressed by the late Professor Jordan of the Department of Bacteriology at Chicago University and by Professor Tanner of the Department of Bacteriology at Illinois University. Jordan (15) states: "It is possible that cases of 'ptomaine poisoning' in man . . . sometimes occur, but there is no doubt that such cases, if they occur at all, are very rare." He adds: "It still remains to be proved that the ptomaines play any really important part . . . in food poisoning, or in so-called gastro-intestinal intoxications." Tanner (16), in summarizing the objections to ptomaine poisoning as a possible cause of illness, states that the toxicity of ptomaines isolated from putrefied foods has not been satisfactorily established; and that investigations of outbreaks of illnesses thought to have been caused by ptomaines have revealed satisfactory evidence that certain kinds of bacteria cause the trouble by their direct effect on the body, rather than indirectly through the medium of some by-product of putrefaction.

The term "ptomaine poisoning" may, therefore, be regarded as a relic of the comparative infancy of the science of medical bacteriology; but the term is commonly employed by the public to designate a rather specific kind of ailment and physicians frequently find it convenient to use the term because it conveys to their patients a definite meaning so far as the nature of the ailment is concerned, even though it is inaccurate with reference to the cause.

Salmonella Food Poisoning

So far as scientists know at present, the bacteria most commonly concerned in causing acute gastro-intestinal illnesses, which we now call "food poisoning," are bacteria of the *Salmonella* group and *Staphylococcus aureus*. The beginning of our knowledge of food poisoning goes back to 1888, when Gaertner, in Germany, isolated a bacterium from an acute case of intestinal illness which quickly followed the eating of spoiled meat. The bacterium was then called *Bacillus enteritidis,* and is now known as *Salmonella enteritidis*. It belongs to a group of bacteria sometimes called the paratyphoid group because they resemble the typhoid bacillus in many respects. It has been reported (17) that at least twenty-seven distinct but closely related bacteria of the *Salmonella* group are known to have caused outbreaks of food poisoning. *Salmonella aertrycke* is the organism of the group most frequently encountered in food-poisoning outbreaks in the United States and in Great Britain (8).

A typical outbreak of Salmonella food poisoning was reported recently in the Journal of the American Medical Association (18). On June 14, 1938, several cases of acute food poisoning were reported to the board of health of a large eastern city. The illness had probably resulted from food eaten at a wedding banquet on June 12. In all, 105 persons were said to have eaten at the banquet, and investigation revealed at least 79 persons had been made ill. At the same time, several cases of similar illness were reported from among 21 young people, ranging in age from 12 to 18 years, who had attended a confirmation party on the same day as that of the banquet. Later investigation showed that all of these young people had become ill. All of the affected persons from both groups had similar symptoms typical of food poisoning: diarrhea, intestinal pain, and vomiting. Several patients cared for in hospitals were reported to have had fever, and many of the others probably had also. The persons became ill on the average of 19 hours after they had eaten the infected food. There were no deaths, and the average duration of illness was 5 or 6 days.

At first, there did not appear to be any connection between the two outbreaks, but investigation disclosed that the same caterer had prepared the meals for both the banquet and the confirmation party; and one item, chopped chicken-liver paste, was served at both meals. The paste was prepared between 8 and 9 o'clock in the morning, and was kept without refrigeration until it was served about 7 o'clock in the evening. The weather was quite warm and conditions were ideal for growth of bacteria in the paste. Of the persons interviewed, among those who had attended the banquet, only those who did not eat the liver paste escaped illness. All of those who attended the confirmation party were infected.

By the time the investigation was started, none of the liver paste was available for bacteriological examination. Consequently the evidence implicating the paste was statistical and circumstantial, but hardly to be doubted. Bacteriological examination of the intestinal discharges of a number of the sufferers, and of one of the persons who had helped to prepare the liver paste, showed the presence of bacteria of the *Salmonella* group.

This outbreak illustrates several characteristics of food poisoning outbreaks in general: (1) It came from food prepared in large quantity, in a place which served the public. (2) A large number of people were affected. It is quite common for a large number of infections to follow a public function, but infections can happen also among families in private homes. (3) The onset was sudden and severe, and the symptoms were typical. (4) There were no deaths, and recovery was relatively rapid. (5) By the time the outbreak was reported to the authorities, none of the offending food was to be had for examination. (6) A bacterium identical with that which contaminated the food was isolated from one of the persons who prepared the food, so he may have been a carrier. (7) Careless handling of the food was evident, especially the lack of refrigeration, on a warm day, that permitted rapid growth of the bacteria.

A wide variety of foods may carry bacteria of the *Salmonella* group. Meat products, especially cold cuts and canned meat and fish, are common sources of infection; and dairy products, including milk, cream, ice cream, and cheese sometimes are sources. Infections frequently result from the eating of custard-filled pastries, and occasionally from the eating of infected vegetables, especially beans and peas. Even such an unusual product as pineapple jelly has been reported as having been the source of infection. It seems that almost any kind of food can convey food poisoning if an infective germ is present, and if the food has been improperly cooked or improperly handled after its preparation. Tanner (16), in his book on food-borne infections and intoxications, lists a number of outbreaks of food poisoning, and gives the number of cases and the sources and circumstances of infection in each instance.

The question arises: How do the responsible bacteria get into the food? In the outbreak reported above in detail, a human carrier may have infected the chicken-liver paste; and it is possible that human carriers may be as important in food poisoning infection as they are in typhoid fever. Where meats and meat products are the sources of infection, the bacteria may come from infected animals. It is unfortunate that, in most outbreaks, the remnants of infected food have been destroyed before the illness is reported to health authorities; and if fresh meat is the source, the butchered animal is even less frequently available. Rats and mice are often considered responsible for food poisoning, and a bacterium, *Salmonella typhimurium,* sometimes identified as a cause of food poisoning, is also the cause of an intestinal disease among rats and mice and may be spread to food from their droppings. Flour and sugar bins could easily be infected that way, and it is thought that custard and cream pastry fillings are often so contaminated. Insects, especially flies and cockroaches, may help to spread bacteria from rodent droppings.

Food Poisoning from Staphylococcus and Other Bacteria

Another cause of food poisoning, now frequently recognized, is *Staphylococ-*

cus aureus. This bacterium is the usual cause of boils and of pus-forming infections following skin injuries such as cuts, bruises, and puncture wounds as from splinters. As early as 1914, it was suggested that the *Staphylococcus* was the cause of milk poisoning, but it was not until 1930 that the discovery was made (19, 20, 21) that *Staphylococcus aureus* was the cause of certain outbreaks of food poisoning, and that several kinds of foods served as carriers. Cream-filled pastries and cakes are frequent sources of Staphylococcus food poisoning, but other kinds of foods have been involved. The symptoms of Staphylococcus food poisoning infections are much like those caused by the *Salmonella* group of bacteria, and outbreaks of infections by both groups of bacteria have much the same characteristics. The outbreak of Salmonella food poisoning described above could just as well have been caused by a *Staphylococcus*: the story would have been practically the same. Some authorities are inclined to think that outbreaks of food poisoning are caused more often by *Staphylococci* than by bacteria of the *Salmonella* group. The method of infecting foods is practically identical for both kinds of bacteria, and accumulating information seems to indicate that about the same list of foods can carry either type of infection.

Other groups of bacteria have been suspected of being the cause of food poisoning. This is especially true of the *Proteus* group, but available information about this group is not convincing. It is not unlikely, however, that future investigations will incriminate other bacteria than those now recognized as causes of food poisoning.

Protective Measures

Regardless of the kinds of bacteria responsible for food poisoning, the public can use the same methods of protecting itself from danger of infection. These methods may be briefly summed up, as follows: (1) Food should be purchased only from dealers known to have clean premises, and to offer good quality merchandise. Such establishments should control rats, mice, and insects in their markets and storage places. (2) If one eats in a restaurant or other public eating place, he should patronize only a first-class place where food is known to be prepared in a clean kitchen, and of clean materials. (3) Public health officials should exercise careful supervision over all quarters where food is offered or prepared for sale. This supervision should include investigation of the health and personal habits of persons engaged, in any way, in the preparation or handling of food. (4) In preparing meals in the home, food should be thoroughly cooked, and refrigeration should be prompt and adequate when perishable food is stored. It may be stated here that there is practically no danger of food poisoning from fresh fruits and vegetables eaten raw.

BOTULISM

In food poisoning, as it has been discussed above, the bacteria themselves set up disease conditions in the intestines of persons who eat contaminated food. The bacteria may, and probably do, produce toxins, but only as the disease progresses. So far as is known, they do not produce any substantial amount of toxin in food before it is eaten; and their toxin, wherever it is produced, is not a deadly poison as is the toxin of botulism. In contrast, the bacteria responsible for botulism manufacture their toxin in food during the process of food spoilage, and when the spoiled food is eaten, it is the toxin that does the damage, not the bacteria. Scientific evidence indicates that the bacteria of botulism can be taken into the body without any harm resulting.

Incorrect use of terms is common in almost any walk of life, and that is true with reference to food poisoning. Botulism is an example of true poisoning, because the toxin of the bacterium is an active poison. "Food poisoning" as discussed in the immediately preceding section of this bulletin is, in reality, infection rather than poisoning. However, by common usage, Salmonella and Staphylococcus infections from foods will probably continue to be known as food poisoning, and poisoning by botulinus toxin will be called botulism.

Food poisoning from the toxin of the botulinus bacteria was probably first observed in Germany in 1735, but did not attract much attention until the latter part of the 18th century. Then the condition frequently followed the eating of large sausages, and was thought to be sausage poisoning. Consequently the term "botulism," from a Latin word meaning sausage, came into use. Cases continued to occur more or less commonly in different parts of Europe, but it was not until 1894 that the true nature of the ailment became known. In that year, von Ermengem isolated the bacterium during the study of an outbreak of botulism from pickled ham that caused 23 cases of illness with three deaths. It is not surprising that the disease was common, even through the 19th century, because methods of preserving foods, particularly meats, were very primitive and refrigeration was practically unknown.

Botulism was considered rare in America until around 1912, but it is probable that many cases of so-called "ptomaine poisoning" may have been botulism. The cause of the disease is a bacterium called *Bacillus botulinus* by the medical profession generally, while bacteriologists have a newer name for it, *Clostridium botulinum.* The bacterium differs from the *Salmonella* and *Staphylococcus* bacteria in two principal respects: It is an anaerobic bacterium, and it produces spores. Anaerobic bacteria are those which will not grow in the presence of the oxygen of the air. This means that the botulinus bacillus has an excellent opportunity to grow in sealed cans or jars of food from which air has been excluded. Spores are bodies by which bacteria propagate, and in that respect they serve the same purpose as do seeds of garden and field plants. Spores will tolerate much higher cooking or sterilizing temperature, and for a longer time, than the bacteria themselves; and this fact means that the botulinus bacillus will survive heat treatment that would easily kill the *Salmonella* or *Staphylococcus* bacteria, which do not have spores. Fortunately, not many of all the known forms of bacteria produce spores. Of those that do, only this one bacterium has been found to cause food poisoning, although there are others that sometimes render food unfit to be eaten.

There are several types of the botulinus bacillus, and their toxins differ considerably in the degree of their poisonous qualities. The type of the bacterium prevalent in the Pacific-Coast and Rocky-Mountain sections of the United States produces a toxin so deadly that a person poisoned with it has considerably less than an even chance to survive. In the eastern part of the United States and in parts of Europe a less dangerous type of the bacterium is found, but even it can cause fatal illness. There has been a widespread belief that there is no danger of botulism from foods grown and canned in the Atlantic-Coast part of the United States, but a few instances are on record that indicate that there is some danger even in that region. For instance, an outbreak attributed to home-canned string beans was reported from the western part of New York State (23) in 1929; and one attributed to home-canned peppers was reported from New Jersey (25) in 1936. A series of investigations by Professor K. F. Meyer (22) of the University of California indicate that the botulinus bacillus, in its several types, is widely distributed over the United States and Europe, and is found also in other parts of the world.

The most prominent symptoms of botulism are prostration, dryness of mouth, difficulty of swallowing, indistinct or double vision, and sometimes nausea and vomiting. Intestinal pain and fever are not usual unless other contaminating bacteria are present also. Death usually results from paralysis of breathing.

A typical outbreak of botulism was reported from western New York State (23). A Christmas dinner was served to 22 people, members of three families. Later investigation indicated that home-canned (cold-pack method) string beans were the responsible food. The beans were reported to have tasted somewhat sour, and all who ate them became ill with typical symptoms of botulism. Ten persons became ill and five died, all but one of them in four or five days. The other members of the party did not eat the beans, and none of them became ill.

In botulism, as in food poisoning, there is seldom any of the offending food available for examination by the time the outbreak becomes evident. The woman who had prepared the meal became quite ill early and died, so no direct information about the beans could be obtained. An empty jar was found which probably had contained the beans. It was empty but had a little rinse water in it which yielded a culture of the botulinus bacillus. Some home-canned (cold-pack method) eggplant from the same home also yielded cultures of the bacillus. The evidence against the beans was circumstantial but convincing.

Botulism differs from Salmonella and Staphylococcus food poisoning in that it is, for the most part, a disease of the home rather than of public eating places. This is because home-canned foods are usually the source of the poisoning. Factory-canned foods sometimes contain botulinus toxin; for instance, Tanner (16) reports a number of outbreaks traced to factory-canned olives and others attributed to a miscellaneous list of canned foods such as corn, onions (shalots), and sweet corn. Modern industrial packing processes are so perfected, however, that there is little danger from them. A vast majority of outbreaks of botulism result from home-canned foods. The botulinus bacillus grows and produces toxin most readily in meats and in non-acid vegetables such as string beans, peas, spinach, beets, asparagus, and sweet corn. Meats and string beans appear to be the most frequent sources of the poisoning. A few instances have been reported (16) in which the toxin developed in canned fruit, canned pears for example.

Preventive Measures

The danger of botulism from home-canned foods is sufficiently great to justify the greatest care, on the part of the housewife, in the choice of canning methods. The cold-pack method so commonly used is dependable, if it is properly carried out, for use with tomatoes and acid fruits, because the botulinus bacillus does not flourish in an acid environment. The bacillus produces spores which are quite resistant to the cold-pack processing temperature, and the only safe method for processing non-acid foods is in a pressure cooker. Steam under pressure is hotter and has greater penetrating power than has steam in an open kettle. At least ten pounds pressure, for not less than thirty minutes, is usually recommended. Farmers' Bulletin 1471, issued by the United States Department of Agriculture, gives full directions for the processing of home-canned foods by steam pressure. Tables are included which give the proper time and temperature for processing different kinds of fruits, vegetables, and meats.

Professor Tanner (24) of the University of Illinois has stated emphatically that steam-pressure sterilization is the only safe method for processing home-canned non-acid vegetables and meats. He states that between 1925 and 1935 (the date of the publication of his article) no outbreaks of botulism were caused by factory-canned foods in America. He adds: "Non-acid vegetables and meats should be processed only under steam pressure, and not in the oven or boiling water bath"; and he states further that relatively few of the state extension services have seen fit to recommend pressure sterilization, even though authorities recognize its importance, even its necessity, for the sake of safety

The seriousness of the menace of botulism is commonly recognized in the Rocky Mountain states and farther west, but there is a feeling of security in the eastern states because few outbreaks have been reported in that section. Enough outbreaks have been reported from Atlantic Coast states, however, to indicate that danger is not lacking. The fatality rate from botulism anywhere is so high that it seems unwise to take any risk from the use of inadequate sterilizing procedures.

Botulinus toxin can be neutralized by heat, and the thorough boiling of all home-canned foods before they are eaten provides an additional safeguard against danger. Such cooking will also destroy other bacteria that might be able to cause trouble. It is unfortunately true that canned food may contain a deadly amount of toxin without there being any "off" taste or odor, or other evidence of spoilage. The botulinus toxin is so deadly that even a mere touching of the tongue to infected food has been known to result in fatal poisoning.

An antitoxin has been developed for immunization against botulinus poisoning. It does not seem to be very effective when it is used on a person in whom symptoms have already developed, but it is usually given in the hope that it may do some good; and there is little else that can be done. When a case of botulism develops in one or two of a group of people, and others may have eaten the infected food, the antitoxin is given as a preventive measure, and seems to be effective.

TRICHINOSIS

Trichinosis, also called trichinelliasis, is not caused by bacteria, but since it is a disease contracted from food, it seems logical to make some mention of it in this bulletin. The disease is caused by a round worm almost microscopic in size. Tanner (16) states that practically all of the outbreaks reported have come from pork. Of the meats eaten by man, pork seems to be the only kind that transmits the disease. The parasite exists in the larval form in the muscle of the hog. These larvae are surrounded by gelatinous capsules, and when a person eats infected pork the capsules are dissolved and the larvae are set free in the stomach. The larvae then enter the intestines where, in about two days, they develop into mature worms. The females produce many young each, and deposit them as embryos directly into the intestinal lining. The young larvae invade the blood stream and finally get into the muscles where they become imbedded and surrounded by their capsules as they were in the muscles of the hog.

During the early stage of the disease, while the larvae are growing to mature worms, and until the new larvae are deposited in the intestinal wall, the patient may have symptoms that could be attributed to Salmonella or Staphylococcus food poisoning. This stage may last up to eight or nine days, and is termed the first period of the disease. The second period is the stage of invasion of the muscles. All over the body the muscles become sore and tender, and especially in the arms and legs. The symptoms could be attributed to muscular rheumatism or rheumatic fever. Pulmonary symptoms sometimes occur and detract attention from the real disease. The last period is that in which the larvae are being surrounded by their capsules, and recovery follows the completion of this process. The patient usually has fever and rapid pulse during most of the course of the disease. An attack usually lasts five or six weeks. The death rate from trichinosis, for the years 1926-1936, was a little over 4 percent, whereas it was over 15 percent 50 or 60 years earlier. It is not known whether this decrease may be attributed to recent attacks being milder, or to the fact that, in former years, only severe attacks were recognized and reported. The disease is not particularly dangerous, but it is important because it disables its victims for such a long time.

A report published recently (26) on the prevalence of trichinosis in the United States shows that between 5,000 and 6,000 cases have been reported since 1842. A number of postmortem examinations in different parts of the United States showed that 12.34 percent of the persons whose bodies were examined had had the disease at some time during their lives. If that ratio were applied to the present living population of the United States, there would be over 16,000,000 people in the country who had been infected at some time.

The prevention of trichinosis is a simple matter. The disease comes from pork, and thorough cooking of the meat will kill the parasites. If everyone would be careful to eat only well-cooked pork, there probably would be no more cases of human trichinosis.

The aim, in preparing this bulletin, has been to present fundamental information about food-borne diseases in a manner comprehensive, yet simple. This information is not often readily available to the general public because it is usually found in books and scientific journals that are available only in libraries maintained for the use of professional men in the fields of public health and medicine. Only those food-borne diseases have been discussed that are important in the every-day life of the average community. Diseases that occur only rarely, or not at all in our country, are not included.

All of us eat, and we all want to avoid diseases when we can. We should be able to achieve that aim in large measure if we take proper care along the lines recommended by authorities and set down in this bulletin. One last word may be added: Cheapness and economy do not necessarily go hand in hand. That is true of all things we buy, and certainly it is true of foods. The merchant who offers quality goods for sale has to pay more for such goods, and the buyer must expect to pay more in consequence; but in many instances, it is possible in that way to purchase a substantial measure of health protection at the same time. That surely is a good investment and good economy.

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AGRICULTURAL EXPERIMENT STATION

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Minerals in Nutrition

There is a realization that many of our common food products may not be as nutritionally adequate as has been generally assumed. These studies were undertaken to gain some factual evidence of the degree and nature of certain mineral deficiencies.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

The investigations reported here were undertaken primarily in the realization of the existence of certain human nutrition problems which, conceivably, might be traceable to deficiencies in the diet. This objective for research conformed definitely to the interests of Dr. Joel E. Goldthwait, an alumnus of Massachusetts State College, who, in his own experience in the medical field, had reached the conclusion that many human ailments might be brought about by deficiencies in the diet—especially deficiencies in the mineral content of the food consumed. As a result of his interest he was instrumental in gaining substantial financial assistance through the good graces of Mrs. Henry Lang of Montclair, New Jersey; and with this support to supplement the general Experiment Station resources, this program became possible.

MINERALS IN NUTRITION

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By James E. Fuller, Department of Bacteriology

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By Walter S. Eisenmenger and Karol J. Kucinski, Department of Agronomy

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IV. The Effect of Kelp and Mineral Supplements on Atherosclerosis in Rabbits Induced by Feeding Cholesterol
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V. Effect of Added Iodine on the Enzymes of Milk and on Other Enzymes
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VI. Added Iodine in Milk and Fecal Bacteria
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VII. Iodine and Bacterial Counts in Milk
By James E. Fuller, Geo. S. Congdon, and Myer Glickstein, Departments of Bacteriology and Dairy Industry

INTRODUCTION

By James E. Fuller, Department of Bacteriology

Experts in nutrition are constantly stressing the importance of so regulating the diet that "deficiency" ailments may be avoided. One usually thinks of vitamins in this connection, and they are very important; but it is now recognized that very serious consequences can result from the deficiency of necessary minerals in the diets of man and animals.

Scientific knowledge concerning the importance of minerals in food has accumulated slowly. It has long been known that calcium and phosphorus are required for the development of bones, that body fluids need a certain concentration of common salt, that there must be iron in the hemoglobin of blood if it is to carry oxygen, and that a certain amount of iodine is needed to prevent the occurrence of simple goitre. These are a few examples of well-known mineral requirements for health.

The knowledge of the need for some of the minerals in nutrition is comparatively recent. It was demonstrated in 1925 that a diet deficient in copper caused anemia in white rats, and that the anemia was relieved by adding small amounts of copper salts to the diet. In 1931, some experiments showed that white rats on a diet deficient in magnesium developed fatal convulsions, and a similar condition has been observed in farm animals. Important discoveries were made in 1931 concerning the importance of manganese in the reproduction and care of the young of white rats. It was reported in 1934 that insulin, used to treat diabetes, contains zinc; and in 1935, that cobalt is important in the nutrition of sheep and cattle. These examples are cited to illustrate the need the body has for minerals. A complete list would be quite long, and space does not permit a detailed statement here of the different minerals the body needs and the use it makes of them.

The opinion is growing among physicians and nutrition authorities that certain disabling diseases, especially arthritis and hardening of the arteries, may be caused by lack of sufficient minerals in the diet, coupled perhaps with vitamin deficiency. The studies reported in this bulletin were undertaken as a co-operative project by several Departments in the College in the hope that some information might be obtained concerning minerals in nutrition. The investigators and their departments are indicated in the reports which follow this preliminary review of the project.

One of the first essentials in studying mineral deficiency in foods is a knowledge of the composition of various fruits and vegetables. In section I of this bulletin are presented analyses of a considerable number of fruits and vegetables, as well as of some cattle feeds. The cattle feeds are important because, in the case of certain minerals, if the feed has an adequate mineral content the milk will be a satisfactory source of the minerals. The analyses included determinations of nutrients (protein and fats) and of iron, copper, manganese, and phosphorus. Accepted analytical procedures were employed in making the analyses.

Section II of this bulletin reports experiments aimed toward increasing the mineral content of field crops by soil treatment. It is known that soils in certain regions may lack essential minerals. In the Rocky Mountain states and around the Great Lakes, for instance, the soil is deficient in iodine and simple goitre is consequently prevalent in these regions. In such circumstances, it is desirable to increase the minerals that are lacking by soil treatment, if that can be done. A number of minerals and a fairly wide selection of crops were investigated.

Mention has already been made of the belief that deficiency of minerals in the diet may be a cause of arthritis which is responsible for a substantial amount of suffering and disability throughout our country. Section III reports a study of scurvy, based on the assumption that this disease might precede arthritis. It is well known that a lack of vitamin C in the diet will cause scurvy, and the resulting swelling and pain in the joints resemble symptoms of arthritis. In this section of the research, a study was made of the use of iodine and of kelp for the prevention and cure of scurvy. Kelp has a fairly high content of minerals, including iodine. Guinea pigs were used as experimental animals because experience has shown that they are particularly good subjects for use in studying scurvy. Iodine was fed to them in milk, and kelp was mixed with their dry feed. The study failed to show that either iodine or kelp had any value in preventing or curing scurvy induced by a ration deficient in vitamin C.

Reports indicate that the vitamin B complex (which contains two separate vitamins: B_1, and B_2 or G) has been used successfully in treating arthritis. It was tried here on guinea pigs suffering from scurvy and failed to prevent the development of the disease. Vitamin C in the diet is the usual cure for scurvy, but in these experiments it was found that the use of the vitamin B complex or of vitamin D with vitamin C was more effective than vitamin C alone in curing scurvy. Since larger amounts of vitamins appear to be needed for the cure of scurvy than the body requires for normal maintenance, the authors suggest that large amounts of the several vitamins should be used in treating arthritis and other degenerative diseases.

The studies reported in section IV were concerned with the effect of iodine and other minerals on hardening of the arteries (called atherosclerosis in section IV, and also commonly called arteriosclerosis). Hardening of the arteries may be produced artificially in rabbits by feeding them large amounts of cholesterol. This is a fatty substance that occurs normally in human and animal bodies, and especially in bile.

When iodine (as potassium iodide) was fed to rabbits along with cholesterol, the damage to the arteries seemed to be greater than when cholesterol alone was fed. Kelp with cholesterol appeared to lessen the severity of the damage done by cholesterol alone. When the ash of kelp, containing its mineral salts, was fed with cholesterol, there was no apparent lessening of the cholesterol damage; but when a mixture of pure salts, identical with those contained in kelp, was fed with cholesterol, the damage from cholesterol feeding was lessened. It appears that kelp feeding has some value in preventing severe damage but the nature of its action is not known.

Since there has been considerable research as to methods of adding iodine to milk, it seemed advisable to study the effect of iodine on the enzymes of milk, on human and animal digestive enzymes, on the fecal flora of animals fed with iodized milk, and on bacteria in milk.

Section V reports studies concerning the effect of iodine on milk enzymes and on enzymes found in human and animal digestive systems. Milk itself contains certain enzymes which some authorities consider beneficial to the health of the consumer. References to such opinions are cited in this section. Among the enzymes normally occurring in milk are catalase and peroxidase, both of which liberate oxygen from peroxide in milk. Lipase, a fat digesting enzyme, also occurs in milk. It is not important that the reader comprehend the exact chemical activity involved in the action of these enzymes, but rather that the effect of iodine on the enzymes may indicate its effect on other enzymes whose activities are better known.

The enzymes from the digestive system studied were two stomach enzymes—rennin which curdles milk, and pepsin which digests protein; and two enzymes poured from the pancreas into the intestine—steapsin which digests fat, and trypsin which digests protein. Both organic and inorganic forms of iodine were employed. The results of the experiments are given in detail in section V. The effects of the iodine varied with the different enzymes. In general, where there was a stimulating effect on enzyme action, organic iodine was mainly responsible and any inhibition observed was usually in the presence of inorganic iodine.

In section VI are reported some experiments concerning the effect of iodine on the fecal bacteria of white rats. This research was based upon the premise that bacteria which digest nitrogenous substances in the intestine may produce chemical compounds that are injurious to health when they are absorbed into the intestine. The colon bacilli are the most numerous bacteria of this kind in the intestines of meat-eating animals. On the other hand, large numbers of acidophilus bacilli are supposed to be beneficial in the intestine, largely because the conditions that encourage their growth reduce the numbers of colon bacilli.

White rats were employed in this study because their food requirements are much like those of man. One group of rats was fed a preliminary meat diet to increase the numbers of colon bacilli in the feces, and another group was fed a preliminary diet of cereal and lactose to increase the numbers of acidophilus bacilli. Then both groups of rats were subdivided into smaller groups which were given separately tincture of iodine, potassium iodide, or organic iodine. Both raw and pasteurized milk were employed.

Results indicated that the iodine in any form had no effect on the numbers of either kind of bacteria studied. In later experiments kelp was added to the diet instead of iodine, and no effect was observed.

The study reported in section VII dealt with the effect of different forms of iodine on the bacterial content of milk, in an investigation of the possibility that iodine might be added to milk as a substitute for pasteurization, and might also have value as a food supplement. Tincture of iodine, potassium iodide and iodine solution, and organic iodine were employed separately. Studies were made with pure cultures of bacteria as well as milk. The results are briefly summarized in the first part of the section. The effectiveness of pasteurization was compared with iodine treatment for the control of milk bacteria. None of the studies indicated that iodine in quantities that the body should receive would control bacteria sufficiently to justify its use for that purpose.

Detailed reports of the studies of the several departments follow in the order in which they have been treated in this review. Much of the experimental work undertaken is so large in scope that the results are necessarily preliminary. A great deal more could and will be done in this Experiment Station to add to the gradually accumulating knowledge of nutrition-deficiency diseases.

I. TOTAL NUTRIENTS AND MINERALS IN HUMAN AND CATTLE FOODS

By Walter S. Ritchie and E. B. Holland,
Department of Chemistry

Foods have been subject to investigation by the Massachusetts Experiment Station since its organization, and experiments have embraced a wide range of products. Recently attention has been directed to minerals because of their importance in human and animal nutrition. Those given particular attention are iron, copper, manganese, and iodine. In the report here presented, fruits and vegetables from different sources have been analyzed for nutrients, including nitrogen and sulfur, and for iron, copper, manganese, and phosphorus.

Collection and Preparation of Samples

Samples of fruits and vegetables were obtained from the State College and vicinity, and vegetables from the Waltham Field Station and from gardens in the eastern part of the State. Similar samples were obtained from other sections of the country for comparison. Cereals, nuts, processed human foods, and cattle feeds were also included in the survey. All fruits and vegetables were expected to be mature and marketable, and in prime condition for use. Both immature and overripe products will vary appreciably in proximate analyses, but to a less extent in minerals. The variety of the fruit or vegetable and the rapidity of growth are also factors causing variation.

The samples were culled as they would be for household use. They were washed if necessary, ground, and then dried in a current of warm air at about 50° C. Under such treatment, the tissue sets quickly with a minimum deterioration in fat and carbohydrates. In the earlier part of the work, the fruits and vegetables were pared or scraped, but the practice was discontinued later. After the samples had been dried, they were ground to pass through a 1-mm. sieve, and then were kept in closed glass containers until they were analyzed. Analyses of products were repeated in successive years for the purpose of comparison. This procedure assisted in leveling variations in plant constituents traceable to seasonal differences in temperature and rainfall.

Basis of Analysis

Most fruits and vegetables as they come from the field contain from 80 to 96 percent of water at maturity, but lose moisture rapidly after they are harvested and particularly during storage. Fruits and garden vegetables are marketed fresh, frozen, canned, or dried. On the other hand, cereals, navy beans, nuts, and industrial by-products such as oil meals are substantially air-dried when they are marketed. In consideration of such a range of moisture content, dry weight seemed to be the only logical basis for comparison. Consequently, in the table, proximate constituents are recorded as percentages and minerals as parts per million (p.p.m.) of the dry weight of the products.

The amount of moisture lost by fruits and vegetables varies with the nature of the product and with the way in which it is handled after it is harvested. Generally the dry weight ranges from 5 to 20 percent of the original weight. Very few products contain less than 5 percent of dry matter, while products that ripen slowly, or those that are exposed to drying as they are stored or shipped, contain more than 20 percent.

Analytical Methods for Nutrient Constituents

Moisture was determined by drying the product to constant weight in a vacuum oven at 50° C.; protein (N x 6.25) by the Kjeldahl-Gunning method; fat by extraction with anhydrous ethyl ether; fiber by the Official Method for Grains and Stock Feeds; and ash by incineration in an electric muffle furnace at a temperature below visible redness (about 510° C.). The crude ash was resolved by acid extraction into two carbon-free portions, one soluble and the other insoluble.

Determination of Minerals

Numerous determinations of the more prominent inorganic elements in plant products have been reported in the literature during the past few decades. The results were obtained largely by gravimetric methods then in vogue. More recently, with the introduction of microchemical colorimetric methods, the determination of mineral elements has received considerable impetus. The results shown in the table were obtained by colorimetric methods based on visual readings with a Duboscq comparator. In the preparation of solutions, wet combustion was found to be more serviceable, more rapid, less subject to contamination, and of wider application than dry combustion, when many samples were involved. Iron was determined by the thiocyanate reaction; copper by sodium-diethyl-dithiocarbamate reagent and extraction with carbon tetrachloride; manganese by periodate oxidation; and phosphorus as molybdenum blue.

Results of Analysis

The results of the proximate analyses for nutrient constituents, as well as the analyses for minerals, are shown in the accompanying table. For comparative purposes, the samples were grouped according to the nature of the products and their use as food, as follows:

Major fruits—large fruits such as apples and peaches
Minor fruits—berries
Garden fruits—pumpkins, squash, melons
String beans
Shell beans and peas
Leaf and stem vegetables—spinach, lettuce, celery, cabbage, onions, asparagus, cauliflower
Cereals, low fiber—without hulls, or with hulls removed
Cereals, high fiber—with hulls, as oats
Nuts
Processed human foods—breakfast foods
Cattle feeds, low protein—hay
Cattle feeds, high protein—grains
Roughage

After water was eliminated, most fresh and processed foods contained about 50 percent of soluble and easily digested carbohydrates (sugars and starch), and some contained up to 90 percent. Appreciable amounts of protein were found in some members of most of the group. Fat was a

Results of Analyses of Human Foods and Cattle Feeds

Food Groups	Original Moisture Percent	Range in Nutrients, Percent (Dry Matter Basis)						Range in Minerals, Parts per Million (Dry Matter Basis)			
		Crude Protein	Crude Fat	Nitrogen-Free Extract	Crude Fiber	Crude Ash		Iron	Copper	Manganese	Phosphorus
						Soluble	Insoluble				
Major fruits	75-90	1.0- 8.5	0.1- 2.0	84-94	1.0- 6.5	1.0- 4.5	0.0 -0.04	tr.- 76	2-13	tr.- 7	200- 1770
Minor fruits	80-92	2.3-16.5	2.0-10.5	52-87	7.0-29.0	1.0- 5.5	0.0 -0.30	10- 176	4-39		590- 2880
Garden fruits	79-97	5.0-20.0	0.5- 3.7	59-86	4.5-15.0	3.5-11.5	0.0 -0.17	21- 129	4-34	tr.- 34	1270- 5630
String beans	90-93	18.0-23.0	1.0	55-63	11.5-12.0	6.5- 9.0	0.02-0.05	81- 112	10-18	14- 19	3550- 4740
Shelled beans and peas ...	55-79	25.0-31.0	1.5	52-65	3.5- 8.5	4.0- 8.0	0.0 -0.03	78- 99	8-22	8- 32	4170- 6690
Leaf and stem vegetables ..	81-96	5.0-40.0	0.7- 4.8	25-79	3.5-14.0	4.0-26.0	0.0 -2.56	27- 617	2-34	tr.-260	1270- 9610
Root vegetables	71-96	2.5-16.5	0.1- 2.0	54-91	1.5-10.5	3.0-17.0	0.0 -0.42	22- 290	5-28	tr.-156	1420- 5000
Cereals, low fiber	-	9.0-21.5	0.5- 6.0	71-86	0.7- 4.5	1.0- 3.0	0.0 -0.68	16- 324	1-26	tr.- 72	1640- 6160
Cereals, high fiber	-	11.0-20.0	2.0- 6.0	65-69	9.0-12.0	2.0- 2.5	1.0 -1.48	38- 74	12-43	20-103	3820- 4320
Nuts	-	11.0-32.0	51.0-72.0	5-17	3.5	2.0- 4.0	0.0 -0.01	tr.- 46	7-22	12- 43	2590- 7520
Processed human foods ...	-	0.1-22.0	0.1- 6.5	71-99.5	0.1- 2.3	0.2 -3.0	0.0 -0.11	2- 73	0-22	tr.- 82	tr.- 4990
Cattle feeds:											
Low protein	-	6.5-22.5	0.2-11.0	56-76.5	0.2-22.0	1.0-10.5	0.0 -0.46	24- 369	2-30	tr.-167	840-16210
Medium to high protein..	-	21.0-48.0	1.5-11.5	28-56	2.5-12.5	1.0- 7.6	0.1 -2.36	113-1087	19-73	tr.-335	2200-11260
Roughage	-	8.0-29.5	1.5- 4.5	41-59	13.0-33.5	4.0- 9.0	0.3 -5.85	210-1537	9-35	14-177	1350- 6900

minor constituent except in nuts. Fiber was present in nearly all products, and it may be noted that fiber tends to increase in most products, except fruits, with maturity and overripeness.

The soluble ash of natural food products varied with environmental conditions and the feeding capacity of plants. Insoluble ash, largely silica, was frequently traceable to the retention of soil particles in the interstices of leaves and stems. When the retained soil exceeds 0.50 percent of the ash, the determination of minerals may be vitiated.

The data given in the table seem to warrant the following deductions: The major fruits are noted for their high carbohydrate content; minor fruits have less carbohydrate and more protein, fat (wax), and fiber; raspberries and blackberries are relatively high in crude fiber. Beans and peas, in common with most leguminous crops, contain considerable protein, and some varieties, especially soybeans, have a high fat content.

The leaf and stem vegetables constitute a diversified group. Wide variations are found in the same variety of plant grown under different environmental conditions. Onions, cabbage, cauliflower, celery, and lettuce frequently vary 50 percent in their nitrogen-free extract, and the quality seems to improve with increase of the extract. Onions are low in protein, and asparagus is high. Leaf greens, celery, and lettuce are fairly high in protein and ash. Most root vegetables are high in carbohydrates, and mangels and radishes contain more than average amounts of protein and ash. Low-fiber cereals are similar to root vegetables in total extract, but they contain more starch. High-fiber cereals contain about the same amount of crude protein as the low-fiber cereals, and slightly less total extract.

Processed human foods resemble the cereals from which they are derived. Cattle feeds are industrial by-products and vary in accordance with their sources and treatment. Forage plants, fed green or dried to farm animals, are naturally high in fiber and ash; and when they are freshly cut, they contain considerable protein. This is especially true of leguminous forage.

Environmental factors that affect the synthesis by plants of the nutrient materials may have a similar effect on the plants' assimilation and utilization of ash constituents. The available supply of minerals in the soil seems to be a more limiting factor than selective absorption in the mineral intake by plants. The following deductions are presented from the results of the analyses:

Garden fruits exceed major and minor fruits in ash content; root, leaf, and stem vegetables are similar to the garden fruits; and cereals, processed human foods, nuts, and cattle feeds are relatively low in ash.

The minerals are subject to greater variations than nutrients by proximate analysis. The differences in mineral content among members of the same plant group, and even among samples of the same variety, were so large that a generalization is all that is justified.

Iron is more abundant than copper or manganese and seems to parallel the soluble ash in some instances. The percentage is increased from fruits and cereals through root vegetables, leaf and stem vegetables, cattle feeds, and roughage. Copper is either not present or not available in most soils, as the amount found in most plants ranged from only 4 to 40 parts per million. The amount of manganese in the foods exceeds copper;

its distribution is similar, but the amounts are more variable. In many instances, 2 grams of material yielded only a bare trace of manganese.

The amount of phosphorus in foods, either natural or processed, is usually much greater than that of any of the other minerals determined, ranging from 200 to 10,000 parts per million. Most of the phosphorus occurs in organic combination with protein and ether-soluble bodies, and the amount appears to increase in order from the major fruits through the minor fruits, root vegetables, cereals, roughage, leaf and stem vegetables, and cattle feeds.

II. THE ABSORPTION BY FOOD PLANTS OF CERTAIN CHEMICAL ELEMENTS IMPORTANT IN HUMAN PHYSIOLOGY AND NUTRITION

By Walter S. Eisenmenger and Karol J. Kucinski
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The object of this part of the investigation was to determine the extent to which plants will absorb mineral elements important in human nutrition from soil treated with salts of the elements. It was the hope that the information obtained would aid in the production of crops richer in minerals, to the end that human and animal nutrition might be improved. The three specific objects of the study were: to determine the general principles underlying the question of the absorption by food plants of mineral elements from the soil; to determine the extent to which plants will tolerate salts of the minerals; and to determine the effects of the mineral salts on the soil itself.

The procedure was to grow vegetable plants on plots of land treated with compounds containing the minerals to be investigated. Observations as to the effects of the minerals on plant growth were made throughout the growing season. After the plants had been harvested and dried, parts of them were analyzed to determine their content of the minerals studied, as well as of others, the absorption of which might have been influenced by the soil treatment.

Experiment 1.—Salts of iron, copper, and manganese were supplied to plots of soil in which onions, beets, swiss chard, spinach, and carrots were grown. The beets, swiss chard, and spinach contained more iron than the onions and carrots, but treatment of the soil with iron salts did not produce a greater iron content in any of the plants than was obtained when they were grown on soil without added iron. The hydrogen-ion concentration of the soil is probably a more important factor in absorption of iron by the plant than the amount of iron salt supplied.

When copper salts were applied to soil, the plants contained more copper than those grown on soil without copper treatment. However, when copper sulfate was applied to soil in concentrations of 160 pounds or more per acre, there was some toxic effect on the plants. Lime added to the soil reduced this toxicity somewhat, but it is not known whether the protective action was due to some chemical action of the lime with the copper or to increased tolerance of the plants induced by the lime.

Analysis of plants for manganese showed inconsistent results from plants grown on manganese-treated plots and on other plots as well. There was, however, some evidence to indicate that the application of manganese to soil may increase the amount of phosphorus in crops.

Experiment 2.—Soils known to be lacking in iron, and growing forage deficient in that element, were treated with soluble organic iron compounds. The average iron content of hay grown on four untreated plots was 0.0273 percent. Hay grown on the same plots treated with iron had an average iron content of 0.0431 percent, an average increase of 57.9 percent in the iron content. The available iron in the soils showed increases varying from 27.4 to 378.9 percent.

Experiment 3.—An area known to be deficient in magnesium was divided into four plots and treated as follows: Plot A, untreated control; Plot B, magnesium added; Plot C, magnesium and calcium added; Plot D, calcium added. Different crops were planted across these plots, and observations were made as to the sensitivity of the different plants to magnesium deficiency, and also as to the intake of calcium and magnesium with the different treatments. On the basis of field observations alone, the apparent tolerance of the crops to magnesium deficiency was as follows:

Tolerant

Alfalfa
Rye
Beans
Soybeans
Sudan grass
Swiss chard
Lettuce
Radishes
Peas
Beets
Millet
Strawberries
Sweet Potatoes
Hollyhocks

Not Tolerant

Rape
Sunflowers
Cabbage
Corn
Cucumbers
Mangels
Watermelons
Muskmelons
Peppers
Buckwheat
Potatoes
Pumpkins
Rutabagas
Tobacco
Tomatoes
Eggplant

Table 1 shows the percentage intake of calcium and magnesium by the plants, and the percentage increase or decrease of these substances with reference to the several soil treatments. When only magnesium was added, all of the plants increased in magnesium content, and seven of the eleven decreased in calcium. When both calcium and magnesium were added, peas decreased in magnesium, and corn and kale in calcium. When calcium alone was added, five of the plants decreased in magnesium and three in calcium. Experience has shown that magnesium is more easily introduced into plant tissue than calcium when additional amounts of substances are added to soil. When magnesium and calcium are added to the soil together, the intake of both may be decreased.

Experiment 4.—It is known that if certain chemical elements are added to the soil in abundance, they are taken in by some kinds of plants in amounts larger than the normal growth and metabolism of the plants require. This is sometimes referred to as "luxury consumption" of elements. Other elements, however, will be taken into plants only in amounts needed. In this experiment, lettuce and cabbage were grown for four successive years on soil to which the cations (sodium, potassium, magnesium and calcium) and anions (chloride, sulfate, and phosphate) were added separately to plots in quantities known to be far in excess of normal plant requirements, but not in sufficient quantity to be toxic. The crops were harvested and analyzed for the added chemicals. (Table 2.)

Although the analyses varied somewhat from year to year, the results showed that the intake of all cations was substantially increased, and that the increases of magnesium and potassium were greater than those of calcium and sodium. Thus, the first two would be much more nearly in the "luxury consumption" class than the last two. Of the anions, phosphorus was increased to the greatest extent in the roots of plants. Percentage increases of chlorine were the highest of any of the elements studied. Sulfur was increased substantially in both tops and roots of lettuce plants, but not in cabbage. Cabbage is noted for its sulfur content; but sulfur is not a "luxury consumption" element, and the cabbage takes in only its normal amount regardless of the presence of an excess of the element in the soil.

TABLE 1.—EFFECT OF SOIL TREATMENT ON CALCIUM AND MAGNESIUM CONTENT OF PLANT TISSUES

(Note: Minus sign indicates decrease.)

Crop	Plot No.	MgO, % by analysis	MgO, percentage increase or decrease	CaO, % by analysis	CaO, percentage increase or decrease
String bean, pod and seed	A	0.42		0.86	
	B	0.52	23.81	0.86	
	C	0.54	28.57	0.96	11.63
	D	0.47	11.90	1.03	19.97
Pea seed	A	0.31		0.18	
	B	0.32	3.22	0.17	–5.55
	C	0.30	–3.22	0.19	5.55
	D	0.29	–6.45	0.22	22.22
Sudan grass seed	A	0.22		0.36	
	B	0.43	95.45	0.37	2.77
	C	0.30	36.36	0.54	50.00
	D	0.38	72.73	0.46	27.77
Kale	A	0.20		3.02	
	B	0.40	100.00	2.74	–9.27
	C	0.33	65.00	2.89	–4.30
	D	0.16	–20.00	2.79	–7.61
Broccoli	A	0.15		4.46	
	B	0.45	200.00	4.36	–2.42
	C	0.37	146.60	6.57	47.31
	D	0.15	0.00	5.48	22.87
Brussels sprouts	A	0.33		0.53	
	B	0.39	18.18	0.55	3.77
	C	0.37	12.12	0.54	1.88
	D	0.31	–6.06	0.40	–24.53
Radish roots	A	0.29		0.76	
	B	0.43	48.27	0.69	–9.21
	C	0.37	27.58	1.00	31.58
	D	0.31	6.89	0.95	25.00
Radish tops	A	0.49		4.35	
	B	0.86	43.02	4.08	–6.21
	C	0.63	22.22	7.05	62.07
	D	0.30	–38.37	6.22	30.06
Bean seed	A	0.283		0.154	
	B	0.331	16.96	0.169	9.74
	C	0.322	13.78	0.191	24.03
	D	0.268	–5.30	0.176	14.29
Corn kernel	A	0.176		0.0158	
	B	0.207	17.61	0.0115	–27.21
	C	0.237	34.65	0.0122	–22.78
	D	0.232	31.81	0.0144	–8.86
Celery tops	A	0.432		1.279	
	B	0.742	71.76	1.222	–3.77
	C	0.710	64.35	2.196	72.44
	D	0.459	6.25	2.536	99.67

Note: Plot A, untreated control.
Plot B, magnesium added.
Plot C, magnesium and lime added.
Plot D, lime added.

TABLE 2.—EFFECT OF CATIONS AND ANIONS ADDED TO SOIL ON THE INTAKE OF THE ELEMENTS BY PLANTS.

Percentage increase over controls. (Minus sign indicates decrease)

	Lettuce tops	Lettuce roots	Cabbage heads	Cabbage roots
Cations				
CaO	25.5	14.3	4.2	32.3
MgO	136.9	13.4	101.0	60.9
K_2O	124.4	233.4	28.8	156.1
Na_2O	47.8	70.1	74.2	69.3
Anions				
P_2O_5	60.4	145.8	20.0	43.7
SO_3	33.3	53.1	–9.0	3.1
Cl	527.7	412.6	364.9	563.1

Experiment 5.—After the encouraging results of the preceding experiment, it was decided to study the intake by plants of elements when added two at a time to soil in quantities known to be excessive but not toxic. Four elements, more or less similar and "higher up" in the electromotive series, were used in the experiment: calcium, lithium, sodium, and potassium. Lithium is not of nutritional or agricultural importance, but it was included in the list because it possesses properties intermediate among the elements used. Cabbage, celery, and lettuce were used as indicator crops. The work is incomplete, but indicates that when sodium and calcium salts were applied together to soil, the calcium intake of the plants decreased. Similar results were obtained when potassium was added with calcium, but the percentage intake of potassium increased. Plants could tolerate lithium only in small quantities; but when potassium and lithium were added together to soil, the intake of lithium was decreased. When cabbage plants were grown in soil treated, with both potassium and sodium, the potassium intake was definitely de~~in~~creased. Apparently sodium can replace potassium in plant nutrition.

The results of these experiments indicate that it is possible to increase the mineral content of some kinds of plants, the increase being dependent on the crop, the mineral, and the other chemical substances present. It seems probable that continued experimentation here and elsewhere may develop procedures by which the mineral content of different food plants may be controlled by cultural methods so that the minerals required by man and animals may be adequately provided.

III. POSSIBLE RELATIONSHIP OF VITAMIN C AND ARTHRITIS

By W. B. Esselen, Jr., and C. R. Fellers,
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An insufficient amount of vitamin C in the diet probably favors the development of certain types of arthritis, according to Rinehart (1, 2) and also Abbasy, Gray, and Harris (3). On the assumption that the above statement is true, experiments were conducted in an effort to determine whether or not minerals and vitamins when added to the diet of guinea pigs would in any way alter the pathological symptoms of scurvy (resulting from a deficiency of vitamin C), which in turn may be a precursor to arthritis. Any positive findings might indicate dietary deficiencies which, when combined with a deficiency of vitamin C, might later favor the onset of arthritis. In certain respects scurvy is similar to arthritis, and in clinical work subacute scurvy has frequently been mistaken for rheumatism.

The Influence of Iodine and Kelp on Scurvy

Both preventive and curative methods were used in studying the influence of iodine and kelp on scurvy. These substances were added to vitamin C-free and vitamin C-deficient diets, and the influence on the resistance of guinea pigs to scurvy was determined. Iodine is sometimes used therapeutically in the treatment of arthritis, and for this reason it was used here. Kelp was used because it is a rich source of other minerals as well as iodine. The iodine was administered to the guinea pigs in the form of iodized milk (i.e., milk with 9 drops of U.S.P. tincture of iodine added per quart). Both iodized raw and iodized pasteurized milk were used in order to find out whether the pasteurization process had any effect on the value of milk for such purposes.

The composition of the kelp employed in this experiment was as follows:

Analysis of Kelp	*Percent*
Moisture	5.0
Protein	5.6
Fat	0.4
Nitrogen-free extract, by difference	40.6
Crude fiber	12.1
Ash	36.3
Total	100.0

Analysis of Ash	*Percent*
(Figures are percentages of dry weight of kelp)	
Iodine	0.15
Iron	0.13
Copper	0.003
Manganese	0.05
Calcium	1.28
Phosphorus	0.29
Sulfur	1.04
Sodium	6.50
Potassium	12.49
Magnesium	0.72
Chlorine	13.67
Total	36.323

The work was carried on with guinea pigs, which, like man, are particularly susceptible to scurvy. Forty animals were used. Young 300-gram guinea pigs were maintained on the Sherman vitamin C-free ration supplemented daily by 2 grams of fresh Baldwin apple. The apple furnished about half of the vitamin C requirement of the animals and simply delayed the onset of acute scurvy. Ten guinea pigs showed scurvy lesions in 17 days, after which they were fed various iodine supplements daily. Twenty guinea pigs were similarly fed iodine supplements after 24 days. Naturally the scurvy was more advanced in these animals. All the guinea pigs were weighed at three-day intervals and autopsied at death. Data are summarized in Table 1.

TABLE 1.—EFFECTS OF IODINE SUPPLEMENTS ON SCURVY IN GUINEA PIGS

Number of Animals		Number of Days before Iodine Supplement Was Fed	Supplement Fed in Addition to C-free Ration and 2 grams of Apple	Average Loss in Weight Before Iodine Therapy Began (grams)	Average Loss in Weight after Iodine Therapy Began		Survival Period after Iodine Therapy Began (Days)	Average Scurvy Score
Total	Data Based on*				Grams	Percent		
			(a) Curative					
5	2	17	10% kelp plus 20 cc. iodized raw milk	67	96	33	19	11
5	4	17	20 cc. iodized raw milk	72	74	27	14	14
6	4	24	10% kelp	77	69	30	28	15
7	6	24	10 cc. iodized pasteurized milk	47	65	26	40	15.8
7	7	24	10 cc. pasteurized milk	32	82	27	53	13.9
			(b) Preventive					
5	5	0	10% kelp plus 10 cc. pasteurized milk	..	120	39	50	12.9
5	5	0	10 cc. pasteurized milk	..	134	43	54	13.7

*Premature death or other causes prevented using all the animals throughout the experiment.

Since only negative results were obtained where curative tests were used, it was decided to try the effect of iodine therapy in the prevention of scurvy. In this experiment 5 young guinea pigs were fed the vitamin C-free ration plus 2 grams of Baldwin apple daily and 10 cc. of pasteurized milk in addition to the kelp. The kelp comprised 10 percent of the ration which was kept before the animals at all times. Five animals were used in the control experiment in which no kelp was fed. Data are given in Table 1.

There is no indication that iodine supplements in the form of iodized raw milk, iodized pasteurized milk, or kelp were of any value in either curing or preventing scurvy in guinea pigs. The animals receiving the iodine supplement lived no longer than the control animals receiving no iodine and showed the same degree of scurvy. Individual growth curves were made for each experimental animal. There was no evidence that the animals receiving iodine lost weight more slowly than the controls. Similarly, no differences were noted at autopsy, among the various experimental animals, in the location or severity of the scurvy lesions.

The Influence of Vitamin D on Scurvy

Massive doses of vitamin D have been reported by Dreyer and Reed (4) and Vrtiak and Lang (5) as being effective in the treatment of arthritis. Following this lead, large doses of vitamin D in the form of viosterol were administered both orally and by intraperitoneal injection to guinea pigs on both vitamin C-free and vitamin C-deficient rations. The data are summarized in Table 2.

In this experiment, vitamin D in large amounts seemed to shorten the life of guinea pigs with scurvy, but the animals which received vitamin D had less swelling in the costochondral and knee joints than did the control animals. It is believed that the animals which received vitamin D died sooner because their metabolic rate was speeded up by this vitamin, as has been demonstrated by other workers. The improved condition of the joints may have been due to the fact that the vitamin D had a favorable effect in preventing calcium deposition in the bones.

The Vitamin-B Complex and Scurvy

The therapeutic use of the vitamin-B complex (vitamins B_1 and G) has also been reported as being successful in the treatment of arthritis. The effect of these vitamins on scurvy was studied in feeding experiments similar to the previous ones, with dried yeast as the source of vitamins B_1 and G. The data are presented in Table 2 (Groups VII and VIII).

The animals which received the yeast grew faster at first than the control animals, but both groups died of scurvy in about the same length of time. The gross pathology of the animals receiving vitamins B_1 and G was as severe as that of the control animals. Thus, even though vitamins B_1 and G promoted better growth in animals deprived of vitamin C, they had no effect on the onset or the gross pathology of scurvy.

Scurvy with a Superimposed Streptococcus Infection

Rinehart and coworkers have shown that when scorbutic guinea pigs are infected with streptococci, lesions are produced in the joints similar to those observed in rheumatic fever. They suggested that a condition of latent scurvy may provide a susceptible host, and when the factor of

TABLE 2.—THE INFLUENCE OF VITAMIN D AND OF VITAMINS B_1 AND G ON SCURVY IN GUINEA PIGS

Group	Number of Animals	Supplement Fed in Addition to vitamin C-free Ration	Weight at Start* (Grams)	Weight at Death (Grams)	Percent Loss in Weight	Length of Life** (Days)	Scurvy Score								
							Swelling				Hemorrhage				Total
							Ribs	Joints	Jaw	Teeth	Ribs	Joints	Intestines	Muscle	
						Vitamin D									
I	3	None (negative control)	337	179	47	27	2.3	3.0	3.0	3.0	2.3	2.3	1.6	1.3	19.0
II	8	10,000 I. U. vitamin D daily ..	293	171	42	23	1.4	1.9	2.9	2.5	1.7	1.9	1.5	1.1	14.9
III	5	1.0 cc. grapefruit juice daily..	284	261	8	58	1.6	2.8	2.2	1.6	2.0	2.0	1.3	0.4	13.9
IV	5	1.0 cc. grapefruit juice daily + 10,000 I. U. vitamin D daily	290	207	29	46	1.1	1.6	2.6	1.8	1.2	1.6	0.7	0.5	11.1
V	2	1.0 cc. olive oil injected three times weekly (control)	330	245	26	19	1.5	2.0	2.5	2.0	0.5	1.5	0.5	2.0	12.5
VI	6	1.0 cc. Viosterol injected three times weekly	282	235	17	19	1.9	2.2	2.1	1.8	2.1	2.7	1.2	0.2	14.2
						Vitamins B_1 and G									
VII	4	None (negative control)	221	161	27	26	1.0	2.2	2.4	1.5	1.5	2.5	1.8	0.5	13.8
VIII	7	10 percent brewers' yeast	211	173	18	26	2.2	2.7	3.0	1.4	1.5	2.4	0.9	0.4	14.5

*Weight at start of experimental feeding.

**Length of life from start of experimental feeding to death of animal.

infection is added to the scorbutic state, the symptoms and lesions of rheumatic fever develop. An attempt was made to duplicate this work, with the idea of finding out whether or not iodine or kelp therapy was of any value in treating scurvy when it was complicated by a superimposed streptococcus infection. The organism employed was a hemolytic streptococcus isolated from a patient in a nearby hospital.

A number of guinea pigs were divided into four experimental groups as follows: 1, control; 2, subacute scurvy; 3, subacute scurvy plus infection; 4, infection only. A saline suspension of the hemolytic streptococcus was injected into the animals in groups 3 and 4 three times a week for four weeks. At the end of this time the guinea pigs showed no ill effects from the streptococcus injections, and their scurvy lesions were not any more severe than were those of the control animals.

The Influence of Vitamin C and Other Factors in Curing Arthropathy

One of the first manifestations of vitamin C deficiency in guinea pigs is an arthropathy which is characterized by pain, swelling, and a limitation of movement in the multiple joints. The joints most obviously involved are the knees, wrists, and elbows. It was the purpose of this study to produce this characteristic scorbutic arthropathy in guinea pigs and then to observe the influence of such substances as yeast and vitamin D, in addition to optimal amounts of vitamin C, on the condition. Suggestive evidence has been found that scorbutic arthropathy in guinea pigs may later lead to an arthritic-like condition in the joints, after the animal has been receiving adequate amounts of vitamin C for a considerable time.

The experiment was planned as follows: A number of guinea pigs were kept on a scurvy-producing diet for 23 days, until typical scorbutic affection of the joints had developed. The animals were then divided into four experimental groups with different dietary regimes (Table 3). From this experiment it was hoped to demonstrate whether or not vitamins of the B complex (as found in yeast) or vitamin D could accelerate the curing of arthritic-like conditions in scorbutic guinea pigs. At the end of four weeks the guinea pigs were killed and autopsied as in the previous experiments. In addition, the femurs were removed from each animal and the percentage of bone ash in them was determined.

TABLE 3.—THE INFLUENCE OF VITAMIN D AND OF YEAST, IN ADDITION TO VITAMIN C IN THE CURING OF SCURVY

Supplement Fed in Addition to C-free Ration	Feeding Period (Weeks)	Weight Gain (Grams)	Scurvy Score	Percent of Bone Ash in Femur
None (control group, killed at start)	0	....	17.0	36.89
10 mgm. ascorbic acid daily	4	117	1.6	42.65
10 mgm. ascorbic acid daily plus 10,000 I. U. vitamin D	4	134	1.1	44.92
10 mgm. ascorbic acid daily plus 15 percent yeast	4	141	0.1	48.06

The data so far obtained indicate that guinea pigs tend to make a more rapid recovery from scurvy and the scorbutic arthritic condition if, in addition to optimal amounts of vitamin C, they are also fed yeast (a source of vitamins B_1 and G) or large amounts of vitamin D. The yeast exerted a more pronounced effect than did vitamin D.

The bone ash studies show that in scurvy there was a considerable loss of minerals from the bones. The mineral content of the bones tended to increase with a progressive improvement in the condition of the guinea pigs. The rate of increase seemed to vary with the speed at which the animals recovered from scurvy. That is, the animals receiving 15 percent of yeast in their diet had the greatest ash content in their bones, those receiving the large amounts of vitamin D were next, and those receiving only the vitamin C supplement showed the smallest gain in bone ash content.

Summary and Conclusions

Although no definite results showing that scurvy is a precursor to arthritis have been obtained, this investigation has yielded some information relative to the control of degenerative diseases. While scurvy was the degenerative disease studied, it would seem that the findings may be applied in some degree to similar pathological conditions.

There was no evidence that iodine or kelp had any influence on the location or severity of scurvy lesions. The experimental animals receiving iodine or kelp did not lose weight more slowly than the control animals.

The rate of recovery from scurvy was not dependent solely upon the presence of optimal amounts of vitamin C in the diet. Diets containing optimal or large amounts, rather than merely adequate amounts, of vitamins B_1 and G, or D, in addition to large amounts of vitamin C, were more effective in curing scurvy than were diets supplemented only with vitamin C.

These findings provide further evidence that the optimum vitamin requirements are much greater than amounts ordinarily considered to be adequate for maintenance requirements. A diet containing optimal rather than only adequate amounts of the vitamins should be used in the control of degenerative diseases, including arthritis, because an optimal amount of vitamins appears to build up the physiological state of the body to a point where the repair of degenerative conditions may be accelerated. Likewise, optimal amounts of vitamins in the diet should protect the body against the onset of degenerative diseases.

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IV. THE EFFECT OF KELP AND MINERAL SUPPLEMENTS ON ATHEROSCLEROSIS IN RABBITS INDUCED BY FEEDING CHOLESTEROL

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Nutritional problems of middle age, particularly those related to degenerative diseases, have received far less attention than those of infancy and early childhood. The man or woman of fifty or sixty is faced with thoughts of arthritis, hardening of the arteries, high blood pressure, cancer, or heart trouble—diseases for which there are no known cures, no antitoxins, no specific remedies. If it could be shown that an excess or a deficiency of one particular food component initiates or aggravates such a disease, a program of prevention would be possible. If feeding experiments with animals can furnish information in this direction, the science of nutrition may come to assume as great importance in middle age as it has for the childhood years.

Atherosclerosis (hardening of the arteries) is a disease that affects first the large artery leading directly from the heart (called the aorta), and later the smaller arteries of the body. In spite of numerous theories, its cause is not known. Is it inevitable or preventable? The structure of the arteries changes as they pass from the aorta into smaller branches. In all these vessels there is a lining membrane composed of a single layer of flattened cells which offers a smooth surface for the flow of blood and protects the blood against contact with other body tissues.

The earliest recognizable changes in the human aorta at the beginning of the disease are slightly elevated flattened, yellowish streaks which may develop throughout the entire aorta as the disease progresses. These elevated patches stand out like solidified drops of paraffin.

In the experimental form of atherosclerosis discussed in this paper, it is evident that something besides aging is happening to the tissues to cause the observed injury. There is interference with the normal functioning of the walls, probably because the cells themselves are being injured. The feeding of cholesterol or feeds containing cholesterol to rabbits has become an effective means of producing an atherosclerosis that is very much like the human disease and that does not occur spontaneously in these animals. This condition is associated with an increase in the cholesterol content of the blood and with a general accumulation of fatty substance known as lipemia. In rabbits the arch of the aorta and the areas around the opening of the arterial branches are the first sites of injury. A progressive increase in the number and size of the lesions follows. The spots appear as elevations of a white, grayish white, or yellowish color. They vary greatly in size, the smallest looking like dots or tiny streaks, while the larger ones range in size up to continuous streaks of considerable magnitude. Sometimes there is calcification in the later stages.

Iodine has long been used in treating atherosclerosis, without exact knowledge of its action. It has therefore been used in an attempt to inhibit the occurrence or course of the experimental disease in animals.

EXPERIMENTAL PROCEDURE

In the series of experiments reported here, an attempt was made to produce atherosclerosis under carefully controlled conditions in rabbits of known age and litter, and to study the effects of various forms of iodine and other inorganic substances in the ration upon the severity of the aortic damage as related to blood cholesterol. Over a period of more than three years, 170 rabbits have been used for these experiments. The rabbits were housed in individual cages and were fed a basal ration of natural foods, modified slightly during the latter half of the work. The basal rations were as follows:

First Series

	Percent
Bran	40
Whole oats	30
Rolled oats	28
Salt	1
Irradiated yeast	1

Second and Third Series

	Percent
Bran	35
Whole oats	28
Rolled oats	30
Salt	1
Crisco	4
Cod-liver oil	1
Yeast	1

Crystalline cholesterol was mixed with the dry ration. Experience with feeding 1 percent cholesterol for ten to twelve weeks proved that the resulting injury was too severe to allow an inhibiting agent to show any appreciable effect. Later work with 0.5 percent cholesterol, or a limited amount of 1 percent, was more satisfactory. Preliminary trials with the larger amounts yielded negative results so far as control of the condition was concerned, but gave valuable information regarding the susceptibility of rabbits to arterial change, and the necessity of more careful control of sex, litter relationship, and food consumption than had been previously used or reported by other investigators.

The literature on this subject indicates that both organic and inorganic forms of iodine may inhibit cholesterol injury, but no one seems to have made a comparison of different forms of iodine under similar conditions. Kelp, a seaweed containing large amounts of iodine, was selected as a natural plant source of the chemical. It is not known just what the form of iodine is in kelp. The value of kelp in the treatment of certain degenerative diseases has been recognized by some individuals in the medical profession, but the reason for its apparent value is not known.

In the experiments here reported, 17 percent of kelp was substituted for an equal amount of bran, since both supply roughage in the diet. Based on an average food intake of 100 grams per day, this amount of kelp would supply 20 to 25 milligrams of iodine per day for each rabbit, subject to some variation in the composition of the kelp and the food intake of individual rabbits. The difficulty of inducing the rabbits to eat all of the kelp in the ration was never entirely overcome in spite of care in grinding and mixing, and the use of a binder to keep the kelp well mixed with the feed. In view of subsequent findings with the kelp ration, these discrepancies tend to strengthen rather than to weaken the conclusions.

Potassium iodide was chosen as the inorganic form of iodine to be used. It was fed as such to the rabbits either in drinking water or mixed with feed in amounts sufficient to furnish 25 milligrams of iodine daily for each rabbit. In some of the rations, described later, the potassium iodide was combined with salt mixtures as a constant percentage of the ration. In most of the experiments, both the cholesterol and the iodine supplements varied directly with the food consumption, the actual amounts eaten being given in the tables.

The cholesterol content of the rabbits' blood was determined every two or three weeks by the Sackett modification of Bloor's original method.[1] Autopsies were performed on all rabbits at the end of the experiments, and a careful record was made of the degree of damage to the aortas, of liver weights, and of other gross pathologic changes.

As mentioned earlier, the feeding of 1 percent of cholesterol caused rapid and marked damage to the aortas of rabbits. The excess of cholesterol in the blood developed soon after cholesterol feeding was started, but with considerable individual variation among the rabbits. In general, the damage to the aortas and other arteries was proportional to the duration of the cholesterol excess. Experience indicated that much of the individual variation might be eliminated if strict attention was given to sex and to litter-mate relationships. It is difficult to obtain large litters of known age and breed and in first-class physical condition, but such selections were made in the subsequent experiments, and the success of the work was dependent on this point.

Effect of Kelp and of Potassium Iodide

Chart 1 summarizes the results relating to the protective action of kelp and of potassium iodide on cholesterol-induced atherosclerosis in the rabbits. The findings are grouped according to ration supplement, with the litters indicated by letters. It is apparent that the kelp supplement tended to reduce the level of blood cholesterol and materially lessened the damage to the aortas. Potassium iodide, on the other hand, caused a significant rise in blood cholesterol and exerted no protective action against damage to aortas. The sex difference which appears in this series of experiments was suggestive of a sex difference in susceptibility to cholesterol injury. Later experiments failed to confirm this finding in every case, although there is still some evidence that males may be slightly less susceptible than females.

The fact that kelp exerted a protective action, and potassium iodide did not, raised the question as to what the active principle in kelp might be. The high total ash of kelp, plus the predominance of basic elements in the ash, suggested the next line of attack. It seemed possible that the damage to the aortas and other arteries might be related to the acid-base balance of the ration. A salt mixture was prepared containing the basic elements of kelp, and the quantity fed was calculated to provide the basic elements equal to the excess of bases present in kelp. To this was added 30 milligrams of potassium iodide per 100 grams of food.

Rations containing 0.5 percent cholesterol—alone, with kelp, and with the salt mixture—were fed to six male rabbits in litter F. The animals receiving the salt mixture developed higher blood cholesterol and more severe damage to arteries than did the animals receiving cholesterol alone, or those receiving cholesterol plus kelp. This led to the discarding of the sex theory as a promising lead for further work. It was apparent that the excess of basic elements could not be the crucial factor, but there was still the possibility that some substance in kelp in addition to iodine might be effective in controlling the damage due to cholesterol.

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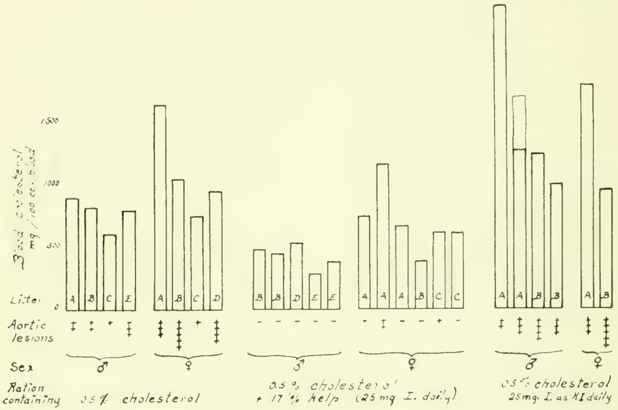

Chart 1. Blood Cholesterol and Aortic Lesions in Rabbits Fed Cholesterol plus Kelp or Potassium Iodide.
Series 1. 61-79 days on experiment.

In reviewing the data thus far presented, the degree of damage seemed to parallel the length of time during which the cholesterol content of the blood remained high, rather than the actual amount of cholesterol eaten. The experimental period in the second set of experiments was, therefore, lengthened and the rabbits were not sacrificed until a marked degree of high blood cholesterol had existed for six to eight weeks. Longer periods resulted in damage so severe that differences in damage due to ration supplements were obscured. At autopsy, the heart, aorta, and liver of each animal were examined as before, and also the kidneys, spleen, and adrenal glands were examined for infiltration and other changes. Four litters were used, under carefully controlled conditions, to check the protective action of kelp observed in earlier experiments. The experimental period was lengthened to seventeen or eighteen weeks. One group of rabbits received the basal ration only; a second group, the basal ration plus 0.5 percent cholesterol; and a third, cholesterol plus 17 percent of kelp substituted for bran in the basal ration. An attempt was made to have a rabbit of each sex from each litter on the same ration to afford the best possible basis for comparison.

The protective action of the kelp was less striking than in earlier experiments, possibly because of the longer experimental period and the more prolonged cholesterol injury. There was some evidence, however, of protection due to kelp among the male rabbits of each litter. The feeding of cholesterol caused a marked increase in liver weights, but the kelp ration reduced this effect by half.

In order to investigate the nature of the active principle in kelp, which appeared to exercise a protective action against cholesterol injury, another series of experiments was planned in which kelp, kelp ash, and a salt mixture resembling the inorganic constituents of kelp, were used as supplements to the ration. The kelp was ashed in a muffle furnace at 400° C. for about 48 hours. A representative sample of the ash showed 1427 parts per million of iodine, or about one third of that theoretically present in the kelp. Thus, the kelp ash represented most of the inorganic material of the kelp, minus about two thirds of the iodine. The synthetic salt mixture was prepared to represent as nearly as possible the inorganic composition of the kelp. Salts used contained both the required anions and cations. Excess base was supplied as carbonate, thus introducing no fixed acid radicals not present in kelp.

For this final series of experiments, 41 rabbits from 6 litters were used. Each litter was divided among the five ration groups, with as even a distribution of sex as possible. The ration groups were as follows: basal ration; basal ration with cholesterol; basal ration with cholesterol and kelp; basal ration with cholesterol and kelp ash; basal ration with cholesterol and synthetic salt mixture. One percent of cholesterol was used in each instance. In the previous experiments cholesterol had been fed ad lib. For the purpose of shortening the duration of the experiment and of insuring a more even consumption of cholesterol regardless of food intake, the cholesterol content of the rations was increased, and exactly 300 grams of the ration fed per week. Kelp constituted 34 percent of the ration in which it was used, and furnished approximately 50 milligrams of iodine per 100 grams of feed. The 12 percent of kelp ash used was equivalent to 34 grams of kelp; and 12 percent of the salt mixture provided a similar mixture of inorganic elements with 50 milligrams of iodine per 100 grams of feed. In this way, each rabbit received about the same amount of cholesterol and other supplements per week. After 300 grams of the experimental ration had been consumed, the basal ration was fed ad lib. All animals were autopsied at the end of ten or eleven weeks.

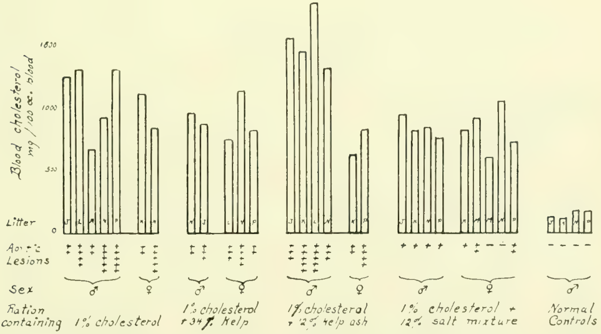

Chart 2. Blood Cholesterol and Aortic Lesions in Rabbits Fed Cholesterol plus Kelp, Kelp Ash, or a Synthetic Salt Mixture.
Series III. 69-76 days on Experiment.

The results are shown in Chart 2. Only animals that gained weight during the experiment are represented in the chart, since it was felt that animals which had lost weight would not give representative results. Loss of weight was caused by refusal of the animals to eat the ration. Few of them ate the kelp satisfactorily, and the few that did gain on the kelp ration failed to show the protective action against cholesterol injury that had been previously demonstrated. There was some evidence that the grain was eaten and the kelp left in the feed cups. The striking findings in this series of tests were the extremely high blood cholesterol and the severe aortic injury in rabbits fed the kelp-ash supplement, and the apparent protection against injury among the rabbits given the salt mixture. The salt mixture did not seem to exert a marked influence on the blood-cholesterol level; but in view of previous findings, that potassium iodide tended to increase the cholesterol content of the blood, the fact that the same compound fed in the synthetic salt mixture failed to have the same effect is worthy of note.

Liver-Cholesterol Determinations

During all of the experiments it was noted that the livers of all rabbits fed cholesterol were heavily infiltrated with fat. The liver weights reported for one series showed marked increase in size, with evidence that kelp gave some protection against fatty degeneration. The question arose as to whether this was a problem of fat or of cholesterol metabolism. In an attempt to answer this question, cholesterol determinations were made on the livers of animals in the last series of experiments. Determinations were made by a modification of the method of Morrow and Sandstrom. From the study of weights and cholesterol contents, it is apparent that both kelp and the mineral supplement tended to restrict damage and lipoid deposits in the livers due to cholesterol. The color and weight of the livers, as well as lessened changes, were evidence of the effect of cholesterol when mineral supplements were fed, but the actual figures for cholesterol content, shown in Table 2, are even more striking.

TABLE 1.—THE EFFECT OF CHOLESTEROL AND OTHER RATION SUPPLEMENTS UPON LIVER WEIGHT

(Litters G, H, I, J)

Supplement in Total Ration Consumed	Number of Rabbits	Liver Weight Grams	Liver weight Percent of Body Weight
None	6	97	2.8
Cholesterol (0.5%)	8	152	4.6
Cholesterol plus kelp (17%)	10	117	3.6

TABLE 2.—THE EFFECT OF CHOLESTEROL AND OTHER RATION SUPPLEMENTS UPON LIVER WEIGHT AND CHOLESTEROL CONTENT
(Litters K, L, M, N, P, Q)

Supplement in Total Ration Consumed	Number of Rabbits	Liver Weight Grams	Cholesterol in Liver	
			Percent	Milligrams
None	2	99	.013	1.3
Cholesterol (1.0%)	6	127	.095	18.8
Cholesterol plus kelp (34%)	4	111	.049	8.7
Cholesterol plus kelp ash (12%)	6	131	.048	9.4
Cholesterol plus salt mixture (12%)	6	115	.051	11.0

SUMMARY

Typical atherosclerosis, similar to the clinical condition in humans, may be produced in rabbits by feeding cholesterol. The condition is probably related to the high cholesterol content of the blood invariably present for some weeks before the damage appears in the aorta.

Previous reports that iodine compounds tend to prevent or inhibit this damage have been investigated, with careful attention to time and to the amount of cholesterol fed, and to sex and litter-mate relationships.

Potassium iodide as a ration supplement, sufficient to supply 25 milligrams of iodine per day to each rat, caused an increase in the blood cholesterol and in the severity of the damage to the aortas.

Kelp, a dried seaweed, in quantities sufficient to supply 25 milligrams of iodine per day to each rat, tended to lower the blood cholesterol and to decrease the severity of aortic damage. The ash of the same amount of kelp, containing about one third of the iodine originally present, gave no apparent protection against cholesterol injury.

A synthetic salt mixture, made to approximate as closely as possible the inorganic constituents of kelp, with potassium iodide as a source of iodine, exerted a definite protective action against aortic damage, but had a less pronounced effect in controlling the blood-cholesterol content.

It must be concluded, from these findings, that some inorganic factors in kelp in addition to the iodine are essential for the protection of rabbits against aortic damage associated with a rise in the blood cholesterol.

V. EFFECT OF ADDED IODINE ON THE ENZYMES OF MILK AND ON OTHER ENZYMES

By Myer Glickstein, W. S. Mueller, and J. H. Frandsen
Department of Dairy Industry

It is recognized that the heating of milk, as in pasteurization, tends to destroy its biological properties (enzymes and vitamins) as well as the bacteria present. From time to time methods have been advocated in which chemical treatment is substituted for pasteurization in the effort to control milk-borne bacteria without injuring these biological properties. Buddeization, which employs hydrogen peroxide, is an example. It was suggested by Goldthwait[1] that iodine added to milk would control the bacteria and at the same time enhance the nutritive properties of the milk. The study here reported was undertaken to determine the effects of added iodine, both organic and inorganic, on some enzymes that occur naturally in milk and on certain enzymes of the intestinal tracts of man and animals.

The possible importance of natural milk enzymes may be suggested by the following citations from the literature: Lane-Claypon (1) suggested that the enzymes are beneficial in infant feeding; Cohen and Ruelle (2) recorded observations showing the beneficial effects of unheated milk for children and suggested that certain enzymes of the milk may be responsible for the effects; Waksman and Davidson (3) advanced the opinion that the enzymes may act as therapeutic agents in the treatment of certain diseases.

It is possible that the addition of iodine and related compounds to milk may have detrimental effects on the enzymes of the digestive tracts of consumers. Clifford (4) reported that the digestion of fish protein by trypsin was delayed by halogen salts of lithium, sodium, and ammonium; Steppuhn and Timofejewa (5) reported that, at pH 3.8, iodine decreased the activity of pepsin; Waksman and Davidson (3) stated that lipase and ptyalin were injured by iodine; according to Haldane (6), all enzyme activity is retarded by iodine; Gerber (7) found that the caseification of milk by enzymes was delayed in the presence of increasing amounts of iodine, and that iodine inhibited the digestion of starch by both vegetable and animal enzymes.

Experimental

All milk samples were obtained daily from the fresh milk supply from the college farm. The raw milk samples were taken in clean bottles and immediately iodized and shaken thoroughly. The pasteurized samples were taken immediately after the completion of the process in the college plant and were promptly iodized. There has been some controversy as to the form of iodine, organic or inorganic, that is best utilized by the body when taken internally. Accordingly it was decided to employ both forms of iodine in the present studies. The organic iodine used was a patented product secured from the Iodine Products Company of New York, and the inorganic iodine was tincture of iodine made to conform to U. S. P. standard.

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[1] Minutes of a conference on nutrition. Massachusetts State College, December 4, 1935.

Effect of Iodine on Some Milk Enzymes

Preliminary trials were made with a series of samples which contained added iodine from as low as 50 parts per million of free iodine to as high as 200 parts per million. As the work progressed, the samples were made up to contain not more than 100 parts per million, because more iodine rendered the milk unpalatable. The effects of both organic and inorganic iodine are shown in Table 1.

TABLE 1.—EFFECT OF IODIZATION ON MILK ENZYMES

Sample	Catalase activity (Milliliters oxygen)	Peroxidase activity (Milligrams purpurogallin)	Lipase activity (milliliters 0.1 NaOH)	
			Initial	16 days
Control, untreated pasteurized milk	0.60	87.66	0.5	2.43
Boiled milk	0.00	trace	0.5	0.50
Milk with 100 p.p.m. tincture of iodine	1.15	99.25	0.5	2.00
Milk with 100 p.p.m. organic iodine	1.43	514.28	0.5	2.15

Catalase.—The presence of this enzyme in normal cows' milk was first shown by Raudnitz (8). The catalase content of milk varies with the breed and with the individual animal. Colostrom and milk from cows in the last stages of lactation contain large amounts of catalase. Several methods have been used for the estimation of catalase; that here employed was the direct oxygen-evolution method, which is simple and accurate. The technique described by Palmer (9) was modified slightly. Twenty milliliters of a milk sample were measured into a graduated fermentation tube. To this were added 20 milliliters of 3 percent hydrogen peroxide solution. The mouth of the tube was stoppered and the contents allowed to fill the neck. The tube was placed in an incubator at 37.5° C. and held there until gas was no longer evolved. The catalase activity is shown in the table as milliliters of oxygen liberated from 20 milliliters of milk.

Peroxidase.—This enzyme is usually considered to be an inherent enzyme of milk. Peroxidase is one of several types of oxidative enzymes which bring about oxidation and reduction of substances, and the formation of organic acids, alcohols, and carbon dioxide. Peroxidase cannot use molecular ogygen; it can act only in the presence of hydrogen peroxide or certain organic peroxides. It differs from catalase in that it liberates oxygen in an active state, while the product of catalase is inactive oxygen in the molecular state.

The method used for the estimation of peroxidase activity was that proposed by Rice and Hanzawa (10). The action is based upon the oxidation of pyrogallol to purpurogallin, and the results are recorded in the table on the basis of the peroxidase number (the weight in milligrams of purpurogallin yielded by 10 milliliters of milk).

Lipase.—Since the term, lipase, is used to designate the enzyme which digests the neutral glycerol fats, its importance in milk should not be overlooked.

A rancid milk is obviously an unmarketable product. It is difficult to estimate the activity of lipase in milk because it is present in such small amounts. The method of Rice and Markley (11) was used for the purpose because of consistent results reported by several investigators. The digestion of fats by lipase results in an increase in titratable acidity, and the data shown in the table are reported in terms of milliliters of 0.1N sodium hydroxide required to neutralize the acidity.

Comment.—The results recorded in Table 1 show that iodine in concentrations as high as 100 parts per million had different effects on the activities of the enzymes studied. Inorganic iodine stimulated catalase activity to a marked extent, and organic iodine was even more effective in this respect. Peroxidase activity was over five times as great in samples containing organic iodine as in those with inorganic iodine or in the control samples. Lipase activity was inhibited by both forms of iodine, with the inorganic showing the more drastic effect.

Effect of Iodine on Some Enzymes of the Digestive Systems of Man and Animals

Rennin.—Commercial calf's rennin was employed, and its clotting time for milk samples was noted. The method used to measure rennin activity was a modification of the Marshall rennin test. Results shown in Table 2 are in terms of milliliters of filtrate obtained in three minutes from milk treated with a given proportion of standardized rennin solution. A greater volume of filtrate indicates a greater inhibition of rennin activity.

Steapsin.—This is a pancreatic enzyme. In determining the effect of iodine on this enzyme, the Raudnitz method (8) for lipase was employed. The amount of free fatty acid measured was calculated as oleic acid, since the oleic-acid number is frequently employed as an index of lipase activity.

Comment.—Both organic and inorganic iodine stimulated rennin activity, and the effect was quite marked with organic iodine. In preliminary trials, where more iodine was used (over 100 parts per million), some inhibition of rennin activity was noted, which increased as the quantity of iodine added to the milk was increased. A possible explanation may be that iodine is concerned in some way with making more calcium salts insoluble in the serum, which would retard rennin action. Inorganic iodine had an inhibiting action on the lipolytic activity of steapsin, even after 48 hours. Organic iodine seemed to have no significant effect on the enzyme.

TABLE 2.—EFFECT OF IODIZATION ON RENNIN AND STEAPSIN

Sample	Rennin activity (milliliters of filtrate in 3 minutes)	Steapsin activity (oleic acid number)		
		Initial	24 hours	48 hours
Control, untreated pasteurized milk	32.3	40.55	98.35	184.67
Milk with 100 p.p.m. tincture of iodine	20.4	40.55	70.48	138.40
Milk with 100 p.p.m. organic iodine	9.7	40.55	94.22	179.63

Pepsin and Trypsin.—The activity of proteolytic enzymes was estimated by measuring the increase of soluble non-protein nitrogen in milk after it had been digested with the enzymes. For the study of pepsin, an artificial gastric juice (0.5 percent hydrochloric acid and 1 percent pepsin) was added to the milk. The mixture was incubated at 37° C., with constant shaking. Nitrogen determinations were made at the beginning of the experiment, and after 2, 4, and 6 hours of incubation. The undigested protein nitrogen was precipitated and removed from the mixture by filtration, and the soluble non-protein nitrogen in the filtrate was determined by the official Kjeldahl method. The results are shown in Table 3 as milligrams of non-protein nitrogen per 100 milliliters of milk.

The same general procedure was followed for trypsin, except that a 2 percent commercial trypsin solution was used and the reaction was adjusted to pH 8.0 to 8.2. Results shown in Table 3 are on the same basis as those for pepsin digestion.

Comment.—Inorganic iodine inhibited the proteolytic activity of both pepsin and trypsin, and the effect of organic iodine was less marked. The amount of non-protein nitrogen resulting from tryptic digestion was greater than that from peptic activity. This may be accounted for by the fact that trypsin carries the digestion of protein to completion and pepsin does not.

TABLE 3.—EFFECT OF IODIZATION ON PEPSIN AND TRYPSIN

Sample	Milligrams non-protein nitrogen in 100 milliliters			
	Initial	2 hours	4 hours	6 hours
	Pepsin			
Control, untreated pasteurized milk	18.15	24.23	36.70	39.55
Milk with 100 p.p.m. tincture of iodine	18.14	21.05	25.25	28.40
Milk with 100 p.p.m. organic iodine	18.14	23.51	31.74	34.42
	Trypsin			
Control, untreated pasteurized milk	17.82	25.35	48.91	70.91
Milk with 100 p.p.m. tincture of iodine	17.81	22.73	32.00	55.75
Milk with 100 p.p.m. organic iodine	17.81	22.16	43.56	65.04

DISCUSSION

The sensitivity of enzymes to their chemical environment is said to be due to their colloidal nature. A slight change in the reaction of the substrate causes marked effects on their activities. In the absence of buffers, for instance, proteolytic digestion may cease, whereas in the presence of buffers, it may continue for some time. In addition to the action of buffers, the following factors may decrease the velocity of enzyme action:

1. Inadequate saturation of the enzyme as substrate concentration decreases. This factor may be ignored in these experiments as an explanation for the effects of iodine, because there was an ample amount of substrate present in the samples tested, as is shown by the unretarded enzyme activity in the control samples.
2. Reversible union of part of the enzyme with reaction products or with the substrate to form an inactive compound, or irreversible destruction of the enzyme. Thus, the depression of the activity of an enzyme may be either a reversible or an irreversible change.

Haldane (6) made the statement that all enzymes so far investigated are destroyed by relatively mild oxidizing agents. In this study it was found that iodine as an oxidizing agent did not destroy the activity of an enzyme completely in any instance. Instead, a progressive inhibition of enzyme activity took place with increasing concentrations of iodine.

Tincture of iodine contains alcohol which depresses the surface tension of the substrate. Lowering of the surface tension causes an increase in adsorption and, as a result, the enzyme becomes inactive, since a large part of it passes into the foam when milk samples are shaken or rotated. This is the explanation given by Waksman and Davidson (3). It is possible that minute quantities of iodine are non-toxic and actually stimulate enzymic activity in a manner similar to the action of certain drugs on the human body. This may explain the stimulating effect of iodine noted with some of the enzymes.

In general it can be said that where there was a stimulating effect on enzyme activity, organic iodine was responsible; and where inhibition was noted, the effect was due to inorganic iodine, with the organic having less effect or none at all.

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VI. ADDED IODINE IN MILK AND FECAL BACTERIA

By James E. Fuller and W. B. Esselen, Jr.
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Advances in the knowledge of the importance of iodine in human nutrition have led to studies of means of increasing the iodine content of foods. Milk, because of its importance as a food, has come in for its share of attention. Cows have been fed inorganic salts of iodine (1, 2, 6), natural feeds containing iodine (4), kelp and other seaweed (1, 3, 7), and iodized milk (5); and substantial increases in the iodine content of milk by these means have been reported. Devereux (8) pointed out the fact that it is not possible to control the concentration of iodine in milk from cows fed upon iodine compounds. He suggested the direct addition of iodine to milk as a means of securing desired concentrations. He employed a colloidal-iodine preparation and reported good results.

It is improbable that the amount of iodine reaching the intestine of a person drinking either naturally or artificially iodized milk would be sufficient to exercise any antiseptic action on the bacteria in the large bowel or in the feces. However, it is known that many substances poisonous to living tissue in certain concentrations are stimulants in much smaller concentrations.

The possible importance of intestinal bacteria in human health is based upon the premise that excessive putrefaction of proteins and excessive fermentation of carbohydrates both produce substances which may be detrimental to health if they are absorbed from the intestinal tract into the body. The coliform group of bacteria, particularly the colon bacillus (*Escherichia coli*), are probably the most active and the most easily studied of the putrefactive and fermentative intestinal bacteria. One of the methods advocated for the control of the coliform bacteria is to replace them with acid-tolerant bacteria (type, *Lactobacillus acidophilus*), which are neither fermentative nor putrefactive. Replacement is effected either by actual implantation of the acidophilus bacteria through the use of acidophilus milk, or by the use of lactose which encourages the increase of acidophilus bacteria normally present in the intestines. This topic has been discussed by Kendall (9).

If it could be shown that a physiologically tolerable amount of iodine in milk would discourage the growth of fermentative and putrefactive bacteria and encourage the growth of acidophilus bacteria in the intestine, then iodine in food would have a value in addition to its strictly nutritional function. If, on the other hand, iodine should be found to encourage the growth of fermentative and putrefactive bacteria, the result would not be so desirable, even though the growth of acidophilus bacteria might be increased at the same time.

This study was undertaken to investigate the possible influence of iodine artificially added to milk on the growth and activities of the groups of bacteria mentioned above, as indicated by bacteria in feces.

Experimental

Young white rats were selected for the experiments because their physiology is much like that of man. Two series of experiments were carried out: 1. A series starting with a high-protein (hamburg steak) diet to induce a high initial putrefactive and fermentative fecal bacterial flora.

2. A series starting with a high-carbohydrate diet (Purina fox chow and lactose) to induce a high initial acidophilus fecal flora. After preliminary feeding periods on these diets, raw and pasteurized milk with and without iodine were added as will be indicated later. Samples of feces were examined twice each week throughout the experiments. Examinations were made for gas production and hydrogen sulfide production, respectively indicative of fermentation and putrefaction; total aerobic bacteria counts; coliform bacteria counts; acidophilus bacteria counts.

High-protein Diet

Twelve young rats were fed hamburg steak for four weeks, with agar-agar added for bulk. Then the animals were separated into four groups and milk was added to the diet as follows: Group 1, pasteurized milk; Group 2, pasteurized milk with iodine added at the rate of 2 milliliters per quart of milk; Group 3, raw milk; Group 4, raw milk with iodine added at the same rate as with group 2. After eight weeks on these diets, the hamburg steak was discontinued and the animals were given only the several milk diets, the amount of milk being increased to compensate for the amount of meat withdrawn. This feeding was continued for four weeks more.

High-carbohydrate Diet

Twelve young rats, practically identical in age and size with those in experiment 1, were fed for four weeks on Purina fox chow and lactose. Then the rats were separated into four groups as above and given similar milk supplements. After eight weeks on the milk supplements, the fox chow was discontinued and the several kinds of milk were given as the only food for another four weeks.

Comment

The amount of food given the rats was sufficient to provide adequate nourishment; and the total amount of iodine administered per day to each rat of groups 2 and 4 of each experiment was somewhat greater, when calculated on a basis of body weight, than would ordinarily be considered adequate for human consumers.[1] Pasteurized milk, as well as raw milk, was included in the experiment because some objectors to pasteurization contend that heating the milk kills acid-producing bacteria, and that the drinking of the milk consequently encourages putrefaction in the intestine and gives putrid stools.

When the data from these experiments were assembled, it became evident immediately that the iodine had not exercised either a demonstrable stimulating or inhibiting action on any of the fecal bacteria. Gas production and hydrogen sulfide production responded in the usual way to the effects of the hamburg steak, the Purina fox chow, and the milk, and without any reference to the presence or absence of iodine. The same was true of the total-bacteria counts, the *B. coli* counts, and the acidophilus counts. Experiments on the effects of meat, milk, and cereal diets on the fecal flora of animals and man are so well known that tabulation of results is not justified here.

The different bacteria counts from individual rats, or from rats of any group, varied greatly from day to day, so that graphs made of the several series of counts presented a confusing array of "hills and valleys" that had no apparent meaning. The data were then considered as averages: for example, the *B. coli* counts for the rats in each "milk" group were averaged for each dietary period. In experiment 1, the averages for the preliminary hamburg-steak diet were taken as 1, and the averages for the meat-plus-milk and for the all-milk diet periods were expressed as ratios of 1. In experiment 2, the averages for the Purina fox chow feeding period were taken as 1, and the averages for the chow-plus-milk and for the all-milk diet periods were expressed as ratios of 1. Again, there was no evidence that iodine exercised any influence on the results. If a trend was noticed in one group of rats, the results of another similarly treated group would show a trend in a different direction.

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[1] The exact data will be furnished to anyone interested, on receipt of request, by the authors of this section of the report.

If there had been positive evidence of any influence on the part of the iodine, a tabulation and analysis of results would be presented here. Since there are no positive findings to report, a detailed presentation of data seems useless. The value of averaging the data is questionable because, if a treatment for an illness is to be effective, a daily progressive improvement in condition is desired rather than extreme well-being one day and a serious relapse the next. In the fecal-flora findings of these two experiments, the results were up and down and no progressive tendency was noted.

Kelp Feeding

Since the iodine added to the ration in the first two experiments was in inorganic form, it was decided to investigate the effect of organically combined iodine on the fecal flora of rats. Kelp has been used as a source of iodine in animal feeding experiments (1, 3, 7), so it was chosen for this study. Kelp supplies other minerals as well, but it is an especially good source of iodine.

Eight young rats were fed Purina fox chow for a preliminary period of four weeks. Then 10 percent by weight of kelp was added to the ration and the experiment was continued for eight weeks more. Bacteriological examinations were made twice each week. Since the gas and hydrogen-sulfide production, and the aerobic and anaerobic counts, had not yielded any significant results in the first two experiments, the examinations for this experiment were limited to the aciduric and coliform counts.

Again, as for the first two experiments, results from individual rats from day to day, or from any group for any one examination period, were so erratic that the only practical method of presenting the data was to average the counts of the whole group of rats for the whole of each diet period. The data were not sufficiently significant to justify the presentation of a table. The results can be summarized in the statement that there was no material change in the aciduric counts; and after the kelp was added to the diet, the coliform counts became almost four times as great as those obtained when the chow alone was fed. The addition of kelp to the diet did not cause any inhibition of bacterial growth, and there was a substantial stimulus of the growth of coliform bacteria. Further study would be necessary to determine what component of the kelp was responsible for this result.

SUMMARY

The experiments here reported included a large enough number of rats, and the feeding periods were long enough, that it seems probable that any iodine influence would have been noted. It still remains possible, even probable, that the use of iodine in milk may be of value in the treatment of certain human ailments. The experiments here reported, while not necessarily conclusive, indicate that iodine exercises its beneficial effects directly on the body of the patients, rather than indirectly through control of intestinal bacteria.

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VII. IODINE AND BACTERIAL COUNTS IN MILK

By James E. Fuller, Geo. S. Congdon, Myer Glickstein
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The preceding section of this bulletin (Fuller and Esselen) enumerated some of the experiments that have been made elsewhere as to methods of increasing the iodine content of milk. Those experiments prompted the study reported here concerning the effect of added iodine on the bacterial content of milk. Two studies were made separately, that of Fuller and Congdon in the Department of Bacteriology, and that of Glickstein in the Dairy Department. The studies are briefly reviewed below.

Fuller and Congdon. Three kinds of iodine were employed: tincture of iodine and Lugol's solution, both made up according to the U. S. P. standard; and a colloidal iodine preparation, Iodine Suspensoid, furnished through the courtesy of Merck and Co., Inc., Rahway, N. J. The Suspensoid was the iodine preparation used by Devereux, referred to in reference 8 in the preceding section of this bulletin (Fuller and Esselen).

The three kinds of iodine were added to samples of milk of graded quality, and the milk was allowed to stand at room temperature. Samples were plated, by the Standard Methods of Milk Analysis technique, after exposure periods of 30 minutes, 2½ hours, 4 hours, and 24 hours.

It was found that the effectiveness of the iodine varied somewhat with different samples of milk, even though their bacterial contents were similar. This may have been caused by some of the iodine being absorbed by, or combined with, protein and fat in the milk. It is obvious that milk samples from different sources could have different fat and protein contents. In general, it may be said that milk with low bacteria content required less iodine than milk with high bacteria content to effectively control bacterial growth. Milk samples with initial bacteria counts of 8,000 to 10,000 per milliliter required from 280 to 300 parts per million of iodine, and milk samples with counts around 50,000 bacteria per milliliter required over 500 parts per million of iodine to keep bacteria counts under control for 24 hours.

Pure cultures of bacteria that may be encountered in milk were inoculated into nutrient broth and into sterile milk. The bacterial species employed were the colon bacillus and the typhoid bacillus, respectively representative of normal and disease-producing intestinal bacteria; the aerogenes bacillus and *Bacillus subtilis*, representative of air and dust-borne bacteria that are harmless to health, but may spoil milk; *Staphylococcus aureus*, a pus-forming bacterium; and *Streptococcus lactis*, a normal milk-souring bacterium. Less iodine was required to control bacteria in broth than in milk. Perhaps this was because there is no protein or fat in the broth to inactivate the iodine. Larger numbers of bacteria required larger quantities of iodine for their control in either medium.

The several bacterial species studied seemed to have about the same degree of susceptibility to all three of the iodine preparations employed. There was no particular choice among these iodine preparations, all being about equally effective when results were determined on the basis of parts per million of free iodine. The experiments indicated that the amount of iodine required to effectively control the bacterial content of even a milk of low bacteria content would be sufficient to spoil the taste for most consumers. In addition, it would probably be unwise for one to consume that much iodine day after day except under the direction of a physician who might prescribe it for some specific purpose.

Glickstein approached the subject from a somewhat different angle. He compared the effectiveness of pasteurization and iodine treatment (50, 100, 150, and 200 parts per million, presumably within the limit of the probable physiological tolerance of consumers) for the control of bacterial growth in several grades of milk. Plates were made from both pasteurized and iodized milk at 12, 24, 48, and 72 hours. Pasteurization was found to be several times as effective as even 200 p.p.m. of iodine. In addition, the iodine seemed to lose its effectiveness as keeping-time increased, while the effect of pasteurization was lasting. The percentage increases of bacteria in iodine-treated milk with high initial bacteria content appeared to be less than in milk with low initial bacteria content. The results of the experiments do not encourage the use of iodine for the control of bacterial growth.

In milk of exceptional quality (plate counts below 1000 per milliliter) a little iodine added to the milk may be all that is needed to hold bacteria in check. However, proper care of the milk, especially prompt and adequate refrigeration, would protect the quality of the milk without resort to other procedures. If it is desired to add iodine to such milk for medicinal purposes, that is another story and is not pertinent here.

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AGRICULTURAL EXPERIMENT STATION

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Biological Control of Mealybugs in Greenhouses

By W. D. Whitcomb

Mealybugs are among the most destructive pests of gardenias and other greenhouse crops, and their control with insecticides is very difficult and expensive. The imported ladybird beetle, *Cryptolaemus montrouzieri* Muls., has been used effectively as a biological control for this insect.

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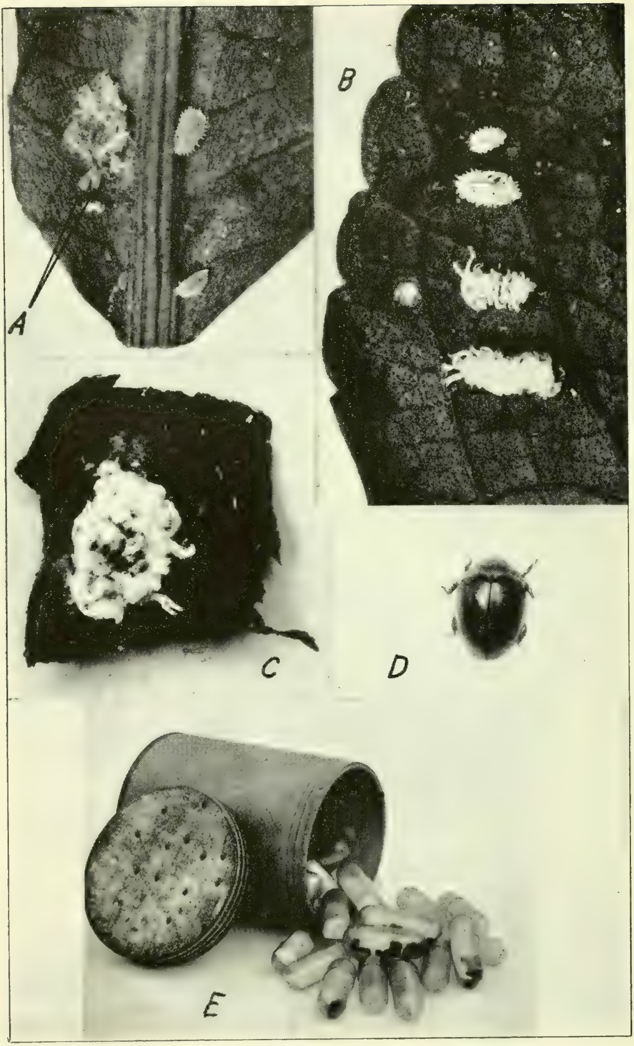

FIGURE 1.
Cryptolaemus montrouzieri Mulsant.

BIOLOGICAL CONTROL OF MEALYBUGS IN GREENHOUSES

By W. D. Whitcomb, Research Professor of Entomology[1]

INTRODUCTION

Biological control, accomplished by the artificial rearing and liberation of parasitic and predatory insects, has been an approved method for combating mealybugs on citrus trees for many years (18). This work has been most extensive and successful in the United States in the citrus orchards of California (14), where experimental studies of various imported insect enemies of the citrus mealybug (*Pseudococcus citri* Risso) and the citrophilus mealybug (*Pseudococcus gahani* Green) (15) have led to practical control of these pests. In the reports of this work, especially those of Armitage (1) and Clausen (2) in California, great importance is placed on the necessity for temperatures and relative humidities that are favorable for the development of the beneficial insect, and it seemed that these conditions either existed normally or could be provided easily in Massachusetts greenhouses, where the citrus mealybug is a destructive pest on gardenias, coleus, and other flowering plants.

The beneficial insect which was used in these studies in eastern Massachusetts greenhouses was the Australian Mealybug Destroyer, *Cryptolaemus montrouzieri* Mulsant, a ladybird beetle of the family *Coccinellidae*.

HISTORY OF CRYPTOLAEMUS MONTROUZIERI IN THE UNITED STATES

Cryptolaemus montrouzieri Muls. is a native of Australia, and was first introduced into this country at California in 1892 by Albert Koebele. The first liberations were made in citrus orchards heavily infested by the citrus mealybug. The colonies which were liberated in San Diego and Santa Barbara Counties have thrived under favorable climatic conditions (16). In many other parts of the State, however, new liberations have been necessary whenever mealybug outbreaks occurred, and hundreds of thousands of these beetles are now raised in insectaries to supplement the surviving population (13). In 1930, colonies of Cryptolaemus were liberated in Florida (20) where they survived, but supplementary liberations were needed to give profitable control of mealybugs.

After the success of the original importation in California was established and demonstrated, Cryptolaemus received international attention and according to Clausen (3) they have been distributed in 35 different countries and in 1936 were known to be established in 15 of them.

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[1] The writer gratefully acknowledges the assistance of Harold A. Wilson, formerly Technical Assistant, and William Garland, Technical Assistant, who made many of the observations reported in this Bulletin.

Legend for Figure 1.

A. Arrow points to eggs of C. montrouzieri which have been moved to the edge of the egg mass of the citrus mealybug in which they were laid (x 1½).
B. Above, two larvae of the citrus mealybug; below, two larvae of C. montrouzieri (x 1½).
C. Pupa of C. montrouzieri, covered with the white waxy filaments of the larval skin within which it pupated (x 3½).
D. Beetle of C. montrouzieri (x 3½).
E. Cryptolaemus montrouzieri beetles in celluloid capsules packed in mailing tube as received by air mail.

The commercial use of Cryptolaemus for the control of mealybugs on plants in the greenhouse is not known to have been reported in literature. Armitage stated in correspondence (March 7, 1933) that liberations of this predator in greenhouses in California "have proven of little value," apparently owing to an unfavorable effect of high humidity on the development of the insect and also to the fact that even though the Cryptolaemus produce a high degree of control they seldom eradicate the mealybugs.

HOST INSECTS

In Massachusetts greenhouses, *Cryptolaemus montrouzieri* has fed upon, and has been reared successfully on, the citrus mealybug (*Pseudococcus citri* Risso), the long tailed mealybug (*P. longispinus* Targ.), and the Mexican mealybug (*Phenococcus gossypii* Towns. and Ckll.).

The native host insect in Australia is the golden mealybug (*Pseudococcus aurilanatus* Mask.) Smith and Armitage (16) state that it "feeds on all the important citrus feeding mealybugs," and in addition to those mentioned above this would include the Citrophilus mealybug (*Pseudococcus gahani* Green.), the Baker mealybug (*P. maritimus* Ehrh.), and the Japanese mealybug (*P. krauhniae* Kuwana).

Van Dine (19) reports that *C. montrouzieri* feeds on the pink mealybug of sugar cane (*P. sacchari* Ckll.).

Wolcott (23) lists the gray mealybug of sugarcane (*P. boninsis* Kuwana= *P. calceolariae* Mask.) and states that these mealybugs were not controlled in the field, where they were protected by the leaf sheaths of the sugarcane.

Wolcott (22, p. 408) reports feeding on the sugarcane leaf scale (*Pulvinaria iceryi* Guerin) in Puerto Rico and also states (23) that a similar record was made by Dozier. Marlatt (8) records feeding on the green shield scale (*Pulvinaria psidii* Mask.) on coffee in Hawaii, and Wolcott (22, p. 408) records this insect on orange and other plants as a host of Cryptolaemus in the West Indies. He also states (23) that Danforth reported it attacking *P. psidii* found on the milk bush (*Rauwolfia nitida*) in Puerto Rico.

C. montrouzieri is recorded as feeding on the pineapple mealybug (*Pseudococcus brevipes* Ckll.) in the Philippine Islands (12), and it is an important natural enemy of the spotted mealybug (*Ferrisiana virgata* Ckll.) in Saipan Island (10) and in Hawaii (21). Williams (21, p. 184) also reports from Hawaii that this predatory beetle prefers to feed on mealybugs living on the exposed parts of plants including *Tylococcus giffardi* Ehrh. on "hala" (*Pandanus*). Other specific hosts in the West Indies are the cocoanut mealybug (*Pseudococcus nipae* Mask.) especially on papaya, mango, and avocado (22, p. 514), and the cottony cushion scale (*Icerya purchasi* Mask.) on casuarina or "pine" trees (22, p. 400-401).

DESCRIPTION

Egg

The eggs are 1.5 mm. long and about one-half as wide, elongate-oval in shape and lemon yellow to dull orange in color. They are laid singly although several may be laid in a group. In the greenhouse all eggs were laid among the woolly filaments of the mealybug egg masses, but Essig (5, 6) reports that on citrus trees which were heavily infested with mealybugs, eggs were laid on the bark, leaves, and fruit. In any case they are placed so that the newly hatched larva can find mealybug eggs for food easily and quickly. (See Figure 1 A.)

Larva

The larvae are oblong to oblong-oval in shape. When newly hatched they are about 1 mm. long and have little covering. As they grow, the body, which is dark yellow in color, becomes covered with white woolly filaments which are generally long, wedged shaped. (See Figure 1 B). The full-grown larvae are about 1 cm. long and one-third as wide, but the white filaments give them the appearance of being nearly twice as large. The head and last abdominal segment, as well as the last three segments of the legs, are black. The abdomen is composed of nine segments which taper toward the rear, the last segment being much smaller than the others. The larvae are quite cannibalistic when an abundant food supply is lacking and eat many eggs and smaller larvae.

Pupa

The pupa itself is about 5 mm. long and bright yellow in color. However, pupation takes place within the woolly covering of the larva so that the general outer appearance is that of a dormant larva. (See Figure 1 C.) On the margin of the abdomen of the naked pupa, there is a characteristic row of short spines. The pupa seems to be a vulnerable stage in the life of this insect and when they are abundant, many dead pupae are found. In the greenhouse, a majority of the pupae were found attached to the underside of the plant benches.

Adult

The beetle is approximately 5 mm. long and 3 mm. wide, having the hemispherical convex shape typical of most ladybird beetles. The head, prothorax, abdomen, and posterior tip of the wing covers are salmon red and the remainder of the body is black. The entire body is covered with short hairs. The head is very small and the black eyes are quite noticeable. The antennae are short and hairy, and the mandibles are split at the tip. There is no distinctive external difference in appearance between the sexes. The beetles are active, especially in warm weather, and fly or run easily when disturbed. They are frequently found resting in the crotches of branches, in the axils of leaf stems, and on the underside of leaves. (See Figure 1 D.)

LIFE HISTORY

Cryptolaemus montrouzieri continues its development and reproduction as long as food is available and climatic conditions are favorable.

Under optimum conditions in the greenhouse, the time required for completing a life cycle extending from the newly laid egg to the adult was about 30 days at 80° F. and about 40 days at 70° F. In these studies no regular and consistent development at 60° F. was observed, but records indicate that the retarding influence of this temperature might extend the life cycle to 105 days. When the larvae were fed only mealybug eggs—which appears to be a deficient diet, although the insects were normal—the life cycle was extended to 54-56 days at 80° F. and to 68-72 days at 70° F. It is probable that any unfavorable conditions which are not fatal may extend the life cycle in much the same way that low temperature did.

Oviposition

In the Greenhouse. In 1933 and 1935, beetles which had been received by air mail from California were paired and confined in jelly glasses in a greenhouse compartment. This compartment was used for various purposes, and the temperature during the winter when the observations were made varied from 40° to 75° F. without any regular control. The beetles were supplied with clusters of mealybugs, usually including a quantity of eggs. Under these conditions the beetles lived from two to three months and laid eggs on 15 to 20 percent of the days.

In 1933, female beetles laid an average of 55.6 eggs during their life, and one laid 107 eggs. On three different days 11 or 12 eggs were laid by one beetle, but the average number of eggs per beetle per day on days when eggs were laid was 3.09.

In 1935, when the beetles were kept in the same greenhouse but under less favorable conditions, the average number of eggs per female beetle was 11.4 and the beetles died about a month earlier than in 1933.

In Constant-Temperature Cabinets. In 1935 and 1937, oviposition records were secured at constant temperatures, using mated pairs of beetles confined in jelly glasses with moist sand in the bottom. Mealybug egg masses on gardenia leaves furnished favorable conditions for oviposition and records were taken daily. The temperature cabinets were not equipped with humidity control and no attempt was made to provide moisture in 1935. In 1937, however, basins of water were placed in the cabinets and these supplied a moderate but variable humidity ranging from 40 to 60 percent.

From Table 1, it is evident that the conditions in 1937 were much more favorable for the beetles than they were in 1935, and the number of eggs laid in these two experiments may be considered as representative of this activity during unfavorable and favorable conditions. Smith and Armitage (16) state that 25 beetles (sex not given) produced in breeding trays 400 to 1,000 adults, which would equal an increase of 16 to 40 per beetle; but that the beetles were confined with their host only 18 days, which represents only one-fourth to one-half of their oviposition period. Furthermore, these figures do not take into consideration the mortality from accidents, cannibalism, or other natural causes. Observations in greenhouses where liberations were made have shown an estimated increase in one generation of 6 to 10 per beetle or 12 to 20 per female beetle.

It is also evident in Table 1 that oviposition is decreased at temperatures below 80° F., and that the number of eggs laid at 60° F. is only about one-third the number laid at 80° F.

TABLE 1. OVIPOSITION OF CRYPTOLAEMUS MONTROUZIERI AT CONSTANT TEMPERATURES. Waltham, Mass., 1935 and 1937.

Year	Temperature	Number of Pairs	Eggs Laid During Life		
			Maximum	Minimum	Average
1935	80° F.	5	....	....	63.8
	70° F.	5	....	....	61.8
	60° F.	5	....	....	24.4
1937	80° F.	2	202	162	182.0
	70° F.	2	134	60	97.0
	60° F.*	2	64	47	50.5

*Temperature fluctuated considerably, especially during some adjustments of the controls, and was higher than 60° F. at times.

Incubation of Eggs

The incubation period was determined from observations of eggs placed in glass tubes partially filled with plaster of Paris and resting on moist sand in petri dishes (11). This method has frequently been used with satisfactory results, and the fact that larvae hatched from not more than 50 percent of the eggs was apparently due to minor injuries resulting from handling and making observations.

TABLE 2. INCUBATION OF EGGS OF CRYPTOLAEMUS MONTROUZIERI AT CONSTANT TEMPERATURES. Waltham, Mass., 1934, 1935, and 1937.

Year	Temperature	Number of Eggs	Incubation Period, Days			Percent of Larvae Hatched
			Maximum	Minimum	Average	
1934	60° F.	8	24	11	19.87	....
	70° F.	5	8	7	7.8	....
	80° F.	8	5	5	5.0	....
1935	60° F.	98	23	9	13.78	19.38
	70° F.	219	11	3	8.28	49.70
	80° F.	308	12	1	4.55	34.30
1937	60° F.	46	18	14	15.28	30.43
	70° F.	69	14	3	8.68	50.72
	80° F.	121	8	4	4.94	46.28

From the records of nearly 900 eggs presented in Table 2, it is apparent that temperatures between 70° and 80° F. are most favorable for the incubation of eggs. At a constant temperature of 80° F., the incubation period of the eggs is about five days; but from 5 to 15 percent more of the eggs hatched at 70° F., and this would indicate somewhat unfavorable conditions for the eggs at 80° F. although the higher temperature corresponds very closely to the conditions reported in California (4). On the plants, however, unhatched eggs were seldom observed and it is doubtful if the mortality under natural conditions is as high as shown in these experiments. At 60° F. the incubation period was two to three weeks, and considering the high mortality it is apparent that this temperature is too low for satisfactory activity or development.

Length of Feeding Period of Larva

According to Smith and Armitage (16) the larval feeding period in their laboratories, where the temperature was approximately 80° F., lasted from 12 to 20 days. In preliminary experiments at Waltham in 1933, on potted coleus plants heavily infested with the citrus mealybug, four larvae were raised in 13 to 21 days, averaging 18 days, at 80° F. In this same experiment, one larva at 60° F. lived more than 60 days without pupating, indicating that development at this temperature is uncertain, if possible at all.

In experiments in 1935 and 1937, in which the larvae were fed only a known number of eggs of the citrus mealybug, the larval feeding period averaged 44 to 55 days at 70° F., and 32 to 53 days at 80° F. (Table 5). These studies were made primarily to determine the rate of feeding on mealybug eggs and the number of eggs necessary to bring the Cryptolaemus larvae to maturity. During the observations a number of eggs, equal to or greater than the number eaten the previous day, was supplied daily, but it is apparent either that the amount of food supplied by the eggs was not sufficient at critical periods of growth or that mealybug eggs alone do not supply all of the food elements necessary for optimum growth of Cryptolaemus larvae. These records also indicate that although the optimum feeding period of the larvae is 18 to 20 days, this period can be extended to 60 to 65 days when the larvae are feeding on mealybug eggs alone without affecting normal larval development.

In greenhouses where Cryptolaemus have been liberated, the larvae fed actively for 25 to 30 days under normal conditions existing in April and May when the average day temperature is 70° to 80° F.

Length of Pupation Period

TABLE 3. LENGTH OF PUPATION PERIOD OF CRYPTOLAEMUS MONTROUZIERI AT CONSTANT TEMPERATURES. Waltham, Mass., 1933.

Temperature	Number of Pupae	Pupation Period, Days		
		Maximum	Minimum	Average
80° F	10	8	6	7.6
70° F.	9	14	8	11.44
60° F.	10	39	21	32.11

Smith and Armitage (16) found that the pupation period of Cryptolaemus in their insectaries was 8 to 12 days, and observations at Waltham showed that this period extended from a minimum of 6 days at 80° F. to a maximum of 39 days at 60° F., with an average duration of 11.44 days at 70° F. It should be noted, however, that pupation occurred readily at a constant temperature of 60° F. even though greatly delayed, while at this temperature death occurred before other developments such as oviposition, incubation of eggs, and larval growth, were completed.

The records secured in 1933 are shown in Table 3.

Length of Life of the Beetles

The average length of life of the beetles in the greenhouse has been about 40 days, although beetles have lived nearly four months when confined in jelly glass cages and supplied with leaves infested with mealybugs, for oviposition records. Several beetles have lived more than three months in the winter and early spring, and one pair was kept alive 114 days. In general, the more favorable the temperature and food supply, the shorter is the life of the beetles, and those having ideal conditions will live less than two months in summer.

The beetles feed moderately on various stages of the mealybugs but do not seem to show any preference for either eggs, nymphs, or adults. When beetles were fed adult mealybugs only for a period of about two months, they ate approximately three full-grown mealybugs in 2 days at 80° F., and one full-grown mealybug in 2 days at 70° and 60° F. Such feeding is not enough to hold the mealybug in check on greenhouse plants.

RATE OF REPRODUCTION OF THE CITRUS MEALYBUG

The average number of eggs laid by the citrus mealybug was determined by placing small larvae and newly hatched crawlers on coleus and gardenia plants and raising them in the constant temperature cabinets operated at 60°, 70° and 80° F. The egg mass was usually completed about five days after the first egg was laid, and crawlers began to hatch from the first eggs at that time. Consequently, counts were made about five days after the first eggs were laid. As shown in Table 4, oviposition although somewhat delayed at 60° F., proceeds at a much more normal

Table 4. Number of Eggs Laid by Citrus Mealybug
Waltham, Mass., 1935

Temperature	Number of Mealybugs Observed	Total Number of Eggs Laid	Number of Eggs Laid Per Mealybug		
			Maximum	Minimum	Average
Average Greenhouse (45°-70° F.)	10	2401	375	175	240.10
Constant 80° F.	11	3763	706	50	342.10
Constant 70° F.	15	4035	502	94	269.00
Constant 60° F.	9	1961	414	82	217.89

rate, in relation to the activity at 70° and 80° F., than it does in the case of the Cryptolaemus.

FEEDING OF CRYPTOLAEMUS LARVAE ON EGGS OF CITRUS MEALYBUG AT CONSTANT TEMPERATURES

Since temperature and humidity had been found to be the most important controlling factors in the development and activity of the Cryptolaemus, an attempt was made to determine in more detail the effect of temperature on the feeding and growth of the larvae.

Equipment and Methods

The temperature controls used in this work were especially constructed cabinets containing about 20 cubic feet. The sides were double glass with one inch air space to increase insulation and to admit sufficient light to permit plants to grow reasonably well. Split-wood blinds on rollers shaded the cabinets and control apparatus from direct sun on clear days, and the doors were closed with refrigerator door latches. The temperature was controlled by means of an air thermostat of the bimetal type with a double mercury-tilt switch. Refrigeration was supplied from coils hung from the top of the cabinet through which methyl chloride was forced by an electrically operated compressor, and heat was supplied from an electric strip heater aided by a small electric fan. This apparatus controlled the temperature within a 3° differential when operated within 30° of the air temperature.

No humidity control was available. In 1935, pots of moist soil provided a fluctuating humidity between 30 and 60 percent which averaged higher in the cooler operated cabinets than in the warmer ones. In 1937, pans of water were supplied in each cabinet, which provided a slightly higher relative humidity which undoubtedly influenced the records to a small extent.

To obtain larvae for the feeding records eggs were collected in the greenhouse and in the rearing cages and placed in glass tubes filled with plaster of Paris and resting on moist sand (11). When the larvae hatched, they were removed with a camel's-hair brush to a gardenia leaf in a jelly glass. Five mealybug eggs, taken from a fresh egg mass, were also placed on the leaf. One Cryptolaemus larva was placed in each jelly glass and the trays of glasses were placed in the temperature control cabinets. Ten larvae were used at each temperature in each series of experiments. Considerable mortality resulted, especially when the larvae were small— generally due to unavoidable injury in handling— and when a larva died, it was immediately replaced with another newly hatched specimen. As soon as the larvae became acclimated to the jelly glass cages, generally in about ten days, about an inch of moist sand was placed in each jelly glass and this was moistened when the daily observations were made.

In determining the number of mealybug eggs eaten, the leaf, the body of the larva, and the sides and bottom of the jelly glass were carefully examined under the binocular microscope and the number of eggs found was subtracted from the number placed on the leaf the previous day.

The number of eggs supplied daily was calculated to equal or slightly exceed the number which the larva would eat, and in most cases the number of eggs was increased by five or ten whenever the daily quota was eaten. It is possible, however, that larvae would have eaten more eggs than were supplied in some of the cages, especially during the periods of greatest feeding just before moulting.

Length of Life of Larvae

Throughout the studies only one Cryptolaemus larva was reared from egg to pupa on mealybug eggs at a constant temperature of 60° F. This individual pupated 99 days after it hatched. At this temperature the other larvae usually died during the second instar, although in 1935 one individual lived 38 days. The average length of life for those larvae which did *not* complete their growth was 25.77 days in 1935 and 12.11 days in 1937.

The larvae which pupated lived slightly longer at 70° F. than at 80° F., the average number of days required to complete their growth at 70° F. being 6 days longer in 1935 and 11 days longer in 1937. At both 70° F. and 80° F., the growth and development of the larvae appeared normal. At 80° F., however, there was more uniformity among the individuals, especially in 1937 when the length of life of 10 larvae, from hatching to pupation, varied only 4 days, compared with a variation of 19 days at 70° F. in 1935. These results are summarized in Table 5.

TABLE 5. LENGTH OF LIFE OF CRYPTOLAEMUS LARVAE (FROM HATCHING TO PUPATION) WHEN FEEDING ON CITRUS MEALYBUG EGGS AT CONSTANT TEMPERATURES. Waltham, Mass., 1935 and 1937.

Temperature	Number of Larvae		Number of Days Larvae Lived			
			Maximum		Average	
	1935	1937	1935	1937	1935	1937
60° F.	9*	1	38*	99**	25.77*	99.**
70° F.	6	8	73	50	61.83	43.88
80° F.	6	10	62	34	55.83	32.3

*None pupated or completed larval growth.

**Only 1 larva completed growth and pupated.

Number of Mealybug Eggs Eaten

In these experiments larvae which completed their growth ate from 1200 to 1400 eggs of the citrus mealybug during their life, or an average of 25 to 36 eggs per day.

In 1935 the average larva confined at 80° F. ate about 30 more eggs than those confined at 70° F., but in 1937 those confined at 70° F. ate more than those confined at 80° F., largely because they lived 11 days longer.

The only larva which completed growth at 60° F. consumed 1328 eggs, which is well within the range of the number eaten at the higher temperatures, indicating that although temperature and other environmental conditions may cause the length of life and rate of feeding to vary, a rather

TABLE 6. NUMBER OF EGGS OF THE CITRUS MEALYBUG EATEN BY LARVAE OF CRYPTOLAEMUS. Waltham, Mass., 1935 and 1937.

Year	Temperature	Number of Larvae	Average Number of Eggs Eaten per Larva: During Life	Average Number of Eggs Eaten per Larva: Per Day
1935	60° F.	12*	46.08*	1.74
	70° F.	5	1397.8	25.21
	80° F.	6	1427.0	26.67
1937	60° F.	1	1328.0	13.41
	70° F.	9*	14.33*	1.18*
	70° F.	9	1279.8	29.2
	80° F.	10	1133.8	35.10

*Larvae did not complete growth nor pupate; number of eggs represents those eaten before death.

constant amount of food is necessary to provide the growth for complete larval development. The maximum number of eggs eaten was 1689 and the minimum number was 1033, and it is apparent that the amount of food necessary for complete larval growth in terms of eggs of the citrus mealybug is about 1350. Variations in the number of eggs eaten are explained by natural vigor of individuals as indicated by difference in size.

TABLE 7. RATE OF FEEDING OF CRYPTOLAEMUS LARVAE ON EGGS OF CITRUS MEALYBUG IN 10-DAY INTERVALS AT CONSTANT TEMPERATURES. Waltham, Mass., 1935.

	At 60° F.	At 70° F.	At 80° F.
Number of larvae	6*	6	6
Average length of feeding period (days)	27.66*	61.83	55.83
		Number of Eggs	
Average number of eggs eaten during life	73.33	1415.00	1505.83
Average number of eggs eaten per day	2.25	22.88	26.99
Average number of eggs eaten per day by 10-day periods:			
1-10 days	2.13	4.83	4.80
11-20 days	2.33 (5)**	13.33	11.40
21-30 days	4.23	25.13	24.83
31-40 days	1.85 (5)**	28.33	41.06
41-50 days	..	30.95	47.47
51-60 days	..	27.75	38.14 (5)**
61-70 days	..	30.20 (3)**	5.50 (1)**
71-80 days	..	37.00 (1)**	..

*None completed growth and pupated.

**Figure in parenthesis represents the number of larvae observed during this period.

Rate of Feeding on Mealybug Eggs

Naturally, the larvae eat more rapidly as they grow larger, and in 1935 during the first 50 days at 70° and 80° F. this increase in feeding was quite regular. When the activity was grouped according to ten-day periods, the maximum feeding occurred in the 41-50 day interval when the larvae ate 30.9 eggs per day at 70° F. and 47.47 eggs per day at 80° F. Some larvae ate 59 eggs in one day during this time, which was the greatest daily feeding recorded in these experiments. Most of the larvae, especially at 80° F., began to pupate within a few days after the 50-day period and after that point the rate of feeding decreased as it does before each moult. At 70° F. the larvae lived about 62 days, and the decreased feeding after the 50-day period was not so evident. Since no larvae lived more than 38 days at 60° F. and none completed larval development, the rate of feeding is not comparable with that at the higher temperatures. It does show, however, that the cooler temperature greatly retarded rate of feeding at all times.

The rate of feeding on mealybug eggs by larvae of *Cryptolaemus montrouzieri* at 60°, 70° and 80° F. is shown graphically in Figure 2.

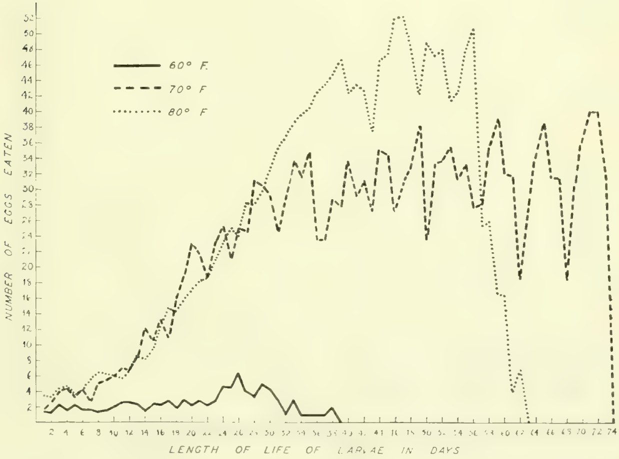

Figure. 2. Rate of Feeding of Cryptolaemus Larvae at Constant Temperatures. Waltham, Mass., 1935.

Determined from the average number of mealybug eggs eaten per beetle per day by Cryptolaemus larvae when supplied with a known number of eggs per day.

	At 60° F.	At 70° F.	At 80° F.
Average number of larvae feeding per day	6.02	5.	5.4
Maximum number of eggs eaten by a larva in 1 day	16	55	59

Feeding During Instars

During the feeding period, the larvae moult four times and their growth is divided into four instars. As shown in Table 8, at 70° and 80° F., approximately 3 percent of the total number of eggs were eaten during the first instar, 12 percent during the second, 25 percent during the third, and 60 percent during the fourth. Since normal development does not take place at 60° F., the records at this temperature naturally vary somewhat from those at the more favorable temperatures.

As shown in Table 4, an average mealybug egg mass contains from 250 to 350 eggs and it is, therefore, apparent that one mealybug egg mass supplies enough food as eggs to feed a Cryptolaemus larva during the first two instars or during the third instar. Furthermore, this indicates that unless several larvae are grouped together at a cluster of mealybugs, the larva will not be forced to migrate in search of food until the third instar or after.

There is a definite decrease in feeding just before each moult which may last only a few hours and be scarcely noticeable in the daily feeding records or may extend over two or three days. In these records the moulting periods were variable but usually occurred at the following times: 5th to 10th day, 13th to 18th day, 23d to 29th day, and 35th to 44th day.

TABLE 8. FEEDING OF CRYPTOLAEMUS LARVAE ON EGGS OF THE CITRUS MEALYBUG AT CONSTANT TEMPERATURES BY INSTARS.
Waltham, Mass., 1937.

		Average Eggs Eaten During—								
		1st Instar		2d Instar		3d Instar		4th Instar		
Temperature	Number of Larvae	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Total During Life
60° F.	1	9.	0.67	149.	11.13	197.	14.72	973.*	72.72	1328.0
60° F.	9**	14.33	-	-	-	-	-	-	-	
70° F.	8	49.0	3.83	108.0	8.43	307.4	24.01	815.5	63.71	1279.88
80° F.	10	33.8	2.99	165.8	14.62	320.2	28.24	614.0	54.15	1133.8

*There appeared to be a fifth moult by this larva at 60° F., due to delayed development at unfavorable temperature, but this was not definitely determined.

**Only one larva lived beyond the 1st instar.

Percentage of Available Mealybug Eggs Eaten

At 60° F. the Cryptolaemus larvae ate only 35 percent of the mealybug eggs supplied to them during the 25 days which they lived, and this further indicates the retarding effect of low temperatures. At 70° F., about 75 percent of the available eggs were eaten, and there was a difference of only about 6 percent between the maximum and minimum which indicates favorable conditions. The greatest feeding was observed at 80° F. where 82 percent of the eggs were eaten, and it is apparent that many of the uneaten eggs were those supplied during the moulting periods of the larvae.

TABLE 9. PERCENTAGE OF AVAILABLE MEALYBUG EGGS EATEN BY CRYPTOLAEMUS LARVAE AT CONSTANT TEMPERATURES.
Waltham, Mass., 1935.

Temperature	Number of Larvae	Av'ge Feeding Period of Larvae, Days	Av'ge Number of Mealybug Eggs Available	Percent of Eggs Eaten		
				Maximum	Minimum	Average
60° F.	9	25.77	155.3	44.74	27.27	35.05
70° F.	6	61.83	1897.3	77.84	71.97	74.64
80° F.	6	55.83	1775.6	91.28	75.63	81.99

PRACTICAL APPLICATION OF CRYPTOLAEMUS IN GREENHOUSES

Source and Supply of the Beetles

The successful control of mealybugs in the citrus orchards of California led to the establishment of several insectaries for the artificial rearing of Cryptolaemus (16). Some of these insectaries were supported by public funds, usually under the direction of the County government; some were supervised by the County and financed by pro-rata charges to the orchardists; and others were entirely maintained by cooperative growers' associations or large private ranches. Later, a few private insectaries operating on a strictly commercial basis were established (17). The beetles used in the experiments herein reported were secured from the Davis-Glendale Company, Glendale, California, a private commercial insectary.

Method of Shipment. Beetles were shipped from California to Massachusetts by air mail, being less than 48 hours en route. In the winter of 1932, several air mail shipments in open airplanes were unsuccessful because the beetles froze, but since then the winter shipments have been made in heated cabin planes with very satisfactory results. With most shipments, a small number of beetles in excess of the order has been included, and in nearly every shipment observed the number of beetles which died en route was less than the surplus.

Only newly emerged beetles are packed for shipment, and these are placed in gelatin capsules about 1¾ inches long and ⅝ inch wide with a small hole in each end for ventilation. Usually, 10 to 20 beetles are confined in each capsule together with a small piece of paper on which they can cling. No food or water is given them in the capsules, and they will live four or five days in this condition unless frozen or overheated. The capsules are then packed in a ventilated cardboard box or mailing tube for shipment. In large orders, about 25 capsules or 500 beetles are packed in one container. (See Figure 1 E.)

Method of Handling for Greenhouse Liberation

When a shipment of beetles is due to arrive, the consignee should arrange to obtain the package as soon as possible after arrival at a convenient point, such as the airport, or by special messenger from the local

Table 10. Summary of Results of Liberations of Cryptolaemus Beetles for Control of Mealybugs on Greenhouse Plants. 1933-1935.

No.	Year	Approximate Date of the Liberation	Location	Average Number of Beetles Liberated	Species of Mealybug	Host of Mealybug	Control of Mealybug by the Cryptolaemus	Estimated Increase of Cryptolaemus	Remarks
1	1933	January 15	Waltham Field Station	1 per plant	***Pseudococcus citri***	Gardenia	To trace in 60 days	4	Free of pest for 4 months.
2	1933	August 10	Waltham Field Station	1 per plant	***P. citri***	Gardenia	Apparently complete in 30 days*	--	Mealybugs under control for 18 months.
3	1934	July 15	Fraser's Wellesley	1 for 2 plants	***Phenococcus gossypii***	Chrysanthemum	Apparently complete in 60 days	8	Free of pest, but not until after bloom of mums.
4	1934	October 10	Roland's Revere	1 for 2 plants	***P. citri***	Gardenia	About 50 percent in 60 days	2	Only partial control; heavy reinfestation in 4 months.
5	1935	April 5	Roland's Revere	3 for 4 plants	***P. citri***	Gardenia	Nearly complete in 60 days**	20	Only slight reinfestation after 6 months.**

*Control was aided by the accidental introduction of the parasite ***Leptomastidea abnormis***.

**A few mealybugs survived on roots and lower stem covered by mulch.

postoffice. This is important because a few hours confinement in a stuffy mail sack, or overheating or freezing, is likely to kill many of the beetles and undo all the precautions which the shipper has taken to insure the arrival of the beetles in a healthy condition. If it is necessary to keep the beetles for some time before liberation, one of the most satisfactory places is a refrigerator in which the temperature is maintained at 45°-50° F. Most florist establishments which handle cut flowers have a refrigerator of this kind.

Method of Liberation. The beetles are liberated simply by releasing them onto the infested plants from the capsules in which they are shipped. In order to facilitate mating and to reduce the tendency to fly soon after they are released, the beetles under observation were liberated in colonies of about 50 at several places in the infested greenhouse rather than one or two beetles on each plant throughout the beds. So far as possible the beetles were liberated in the morning or evening in order to avoid high temperature and bright light which tends to excite them. It has been reported that beetles flew out of the greenhouse through the ventilators as soon as released, but this never happened in the liberations observed, which were made as stated above.

Results of Greenhouse Liberations

During the progress of these experiments, the practical application of Cryptolaemus beetles for the control of mealybugs in the greenhouse was studied from four liberations on gardenias infested with the citrus mealybug, and from one liberation on chrysanthemums infested with Mexican mealybug. These observations are summarized in Table 10.

Factors Influencing the Success of Liberations

In general, these demonstrations have shown that Cryptolaemus will control mealybugs in the greenhouse under Massachusetts conditions even to the point of nearly complete eradication, but that there are several factors governing the satisfactory use of these beetles which may interfere with the customary operation of the greenhouse and reduce the practical advantages of their use. These factors are:

1. The abundance of the mealybugs at the time the beetles are liberated.
2. The number of beetles liberated.
3. The time of year when beetles are introduced as it affects their rate of development.
4. The susceptibility of infested plants and the customary conditions for growing them.
5. The use of insecticides to control other pests.

1. *Infestation of Mealybugs.* A heavy infestation of mealybugs, providing an abundance of food for the Cryptolaemus larvae and favorable locations for oviposition, usually stimulates reproduction. Under such conditions the beetles may lay several times as many eggs as where few mealybugs are present, and the resulting control will be more complete and more quickly accomplished than if the infestation was light and scattered so that the beetles did not lay eggs on as many of the infested plants. If only a few Cryptolaemus larvae are present, they frequently stay on the infested

twig where they were hatched and do not migrate to adjacent infested stems unless they become hungry. To permit the development of a heavy mealybug infestation usually causes more damage to the plants than is practical in profitable flower production, and is so contrary to good greenhouse operation that florists do not favor it. Such a condition was purposely allowed to develop in liberation No. 5, and although the final control of mealybug was excellent, the crop of flowers previous to control was below normal and unprofitable.

2. *Number of Beetles Liberated.* In these observations the heaviest liberation was at the rate of one beetle per plant, and this number gave satisfactory control of mealybugs on gardenias in about 60 days, or after the second generation of larvae had developed. Theoretically, the more beetles that are liberated the more quickly the infestation will be brought under control. In liberation No. 5, Table 10, the infestation on large gardenia plants was extremely heavy and it did not appear that liberations at the rate of three or four per plant would eradicate the pest in one generation, while a liberation at the rate of three for each four plants was very effective after the development of the second generation. A supply of beetles equal to three or four per plant would increase the expense, apparently without proportionately greater benefits, and under normal infestations the liberations of beetles at the rate of one per plant seems most satisfactory on gardenias.

Chrysanthemums not only grow close together in the beds but are also a comparatively short-time crop. A treatment that required two months to produce results would probably permit too much injury by the pest before the benefits took place to meet the practical requirements of the florist.

In liberation No. 3, Table 10, Cryptolaemus beetles liberated at the rate of one for each two plants of chrysanthemums satisfactorily controlled a heavy infestation of the Mexican mealybug by the time the second generation of larvae had developed. However, this did not occur until many of the flowers had been cut for sale, and the results were generally unsatisfactory to the florist. If the liberation had been made two or three weeks earlier, the results would have been much more profitable, and beetles at the rate of one per plant rather than one for each two plants would have prevented serious damage to the plants before actual control was obtained. This observation indicated that liberations should be made not less than 10 weeks before control is desired.

3. *Time of Introducing Beetles.* As shown in the studies on the effect of temperature, development of the Cryptolaemus beetles is not satisfactory below 70° F.; therefore these beetles should not be liberated unless the average temperature will be maintained at about 70° F., or higher, while the beetles are developing through two generations. Greenhouse temperatures are generally less than 70° F. during the winter and heating costs would prohibit the maintenance of such temperature during the cold weather. Therefore, liberation of Cryptolaemus beetles is practical only from about April 1 to July 1 when the prevailing greenhouse temperature will be 70° F. or higher in the following ten weeks. These points were demonstrated in the case of liberation No. 4 made on October 10, when cool weather in November and December so delayed beetle activity and development that only a 50 percent reduction in mealybug resulted.

4. *Susceptibility of Infested Plants.* In general, gardenias and chrysanthemums, especially when grown in large numbers, are adapted to the use of Cryptolaemus for control of mealybug. Gardenias are semi-tropical plants favoring high temperatures and the same plants are usually grown for three or more years in the same beds. The bushy growth and waxy leaves of this plant, resembling citrus, is a natural environment for both the mealybug and the Cryptolaemus. Small pot plants such as coleus, ivy, and geraniums, which are frequently infested with mealybugs, are grown at lower temperatures and are not handled in a way favorable to the development of Cryptolaemus.

5. *Use of Insecticides to Combat Other Pests.* Naturally, the use of sprays or fumigants during the development of the beneficial insect will affect its activity, and should be avoided as much as possible. If plant lice, thrips, or red spider become abundant, however, it may be necessary to check them. In general, Cryptolaemus and other ladybird beetles can withstand the common contact sprays and fumigants at concentrations which control the more susceptible insect pests; and Pratt, Swain and Eldred (9) showed that only 15 percent of the Cryptolaemus were killed by a 10-minute exposure to a .2 percent concentration of hydrocyanic acid gas. Haug and Peterson (7) showed that a very high percentage of the convergent ladybird beetles were killed by phenothiazine and derris; a moderate percentage by nicotine sulfate, Paris Green, and calcium arsenate (under certain conditions); and an insignificant percentage by Bordeaux mixture, fluosilicate mixtures, pyrethrum, arsenate of lead, and manganese. In our own experiments, the beetles survived fumigations with nicotine smoke which effectively controlled aphids and they were not seriously affected by application of lead arsenate for combating chewing insects. Heavy syringing with water which broke the mealybug egg masses where the eggs of the Cryptolaemus were laid reduced the rate of reproduction of the beetles and was more harmful to the final beneficial effect of the predators than most insecticidal treatments.

Theory of Mealybug Control of Cryptolaemus

In this discussion, the first generation eggs, larvae and beetles refer to those which developed from the original beetles liberated. The second generation eggs, larvae and beetles refer to those which developed from the first generation beetles.

In practical application, it has been demonstrated that Cryptolaemus larvae will control a moderate or heavy infestation of mealybugs on gardenia or chrysanthemum in about 60 days, provided conditions for their development are favorable. Due to the check of packing and shipping, the original beetles which are liberated normally lay a variable but usually a small number of eggs so that the number of larvae of the first generation is not uniform and is difficult to estimate. The function of the first generation is to insure the establishment of the predatory insect. The larvae and beetles of the first generation are normally active and feed ravenously but in the greenhouses under observation, where liberations were made at the rate of one beetle per plant or less, the first generation has never given economic control. However, the activity of the first generation has held the mealybug in check so that the more abundant second generation larvae have been able to devour all available mealybugs. In each case observed, a few mealybugs have been protected by soil, mulch, or parts of the plants where the Cryptolaemus larvae did not find them and, therefore, eradication was not complete.

The average life cycle of the beetle in favorable conditions is 40 days (p. 5) and the incubation of eggs of the second generation will require about 8 days. Thus, the larvae of the second generation will start to feed on the mealybugs about 48 days after the original beetles are introduced.

The activity of the second generation larvae of Cryptolaemus is more uniform and can be estimated from the calculations in Table 11. At 70° F. there are 269 eggs in a mealybug egg mass. The Cryptolaemus larva eats an average of 27.21 eggs per day. Therefore, each larva will eat all the eggs in a mealybug egg mass in 9.89 days. At 80° F., 10.89 days will be required, by similar calculations. During its life, the larva eats an average of 1338.8 eggs which is equivalent to the number of eggs in 4.94 mealybug egg masses.

The calculated number of second generation larvae which will develop from each pair of beetles of the first generation is 39.9. Thus, each of about 40 larvae will be eating all the eggs in a mealybug egg mass in 9.89 days, and each larva will eat 4.94 mealybug egg masses during its life. In other words, under normal conditions of reproduction and development, each pair of Cryptolaemus beetles which become established in the first generation after liberation will produce a sufficient number of larvae to destroy about 200 mealybug egg masses during their life.

Actually, the older larvae eat all stages of the mealybug instead of the eggs only, thus influencing the number of eggs eaten and the length of the feeding period of larva. At the same time, many larvae are killed by accidents and by cannibalism so that the increase in population is less than the theoretical number. It should also be noted in Table 11 that the average length of life cycle of Cryptolaemus at 70° F. is about equal to that of the mealybug, but at 80° F. the life cycle of the beetle is 16.6 days shorter. Thus, at the higher temperatures, the activity of the predator is stimulated to a much greater extent than that of the mealybug.

TABLE 11. THEORETICAL CONTROL OF MEALYBUGS BY CRYPTOLAEMUS.

	At 80° F.	At 70° F.
Average number of mealybug eggs per egg mass*	351.18	269.0
Average length of life cycle of mealybug in days*	75	73
Average length of life cycle of Cryptolaemus in days	56.3	72.9
Average number of mealybug eggs eaten by Cryptolaemus larva during feeding period	1322.2	1338.8
Average number of mealybug eggs eaten by Cryptolaemus larva per day	32.14	27.21
Number of days required for the average Cryptolaemus larva to eat eggs in average mealybug egg mass	10.89	9.89
Number of mealybug egg masses eaten by the average Cryptolaemus larva during feeding period	3.77	4.94
Average number of eggs laid by Cryptolaemus beetles	122.9	79.4
Percent of larvae hatched from total eggs laid	40.29	50.21
Number of larvae hatched in succeeding generation	49.5	39.9

*1935 records only; all others are the average of 1935 and 1937 records.

SUMMARY

Cryptolaemus montrouzieri Muls., which is one of the imporant natural enemies of mealybugs infesting citrus trees in California, has been reared on the citrus mealybug and the long tailed mealybug on gardenias and the Mexican mealybug on chrysanthemums, under normal conditions in Massachusetts greenhouses.

In experiments, Cryptolaemus larvae ate about 1325 mealybug eggs, the equivalent of 3 or 4 mealybug egg masses, during their life and completely eradicated an average mealybug egg mass in 9 or 10 days.

A constant temperature of 60° F. definitely retarded the development and activity of the beetle so that it did not hold the mealybug in check, but satisfactory results were obtained at 70° and 80° F.

Practical control of mealybugs by this predatory beetle was secured:

1. From April 1 to September 1, when a temperature above 70° F., which would stimulate the development and activity of the beetle, could be maintained.

2. When the infestation of mealybugs was great enough to provide adequate food without causing unprofitable injury to the plants.

3. On plants which will tolerate warm growing conditions favorable to the activity of the beetle.

4. When the beetles were liberated at the rate of 1 for each gardenia plant or 1 for each 2 chrysanthemum plants.

5. When the use of insecticides necessary to control other pests did not kill the majority of the beneficial predators.

When these conditions were provided, as described in detail, *Cryptolaemus montrouzieri* controlled or eradicated a heavy infestation of mealybugs within 9 or 10 weeks after they had been successfully liberated and a normal number of second generation larvae had developed.

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The Culture and Forcing of Easter Lilies

By Harold E. White

Temperature is an important cultural factor in the forcing of Easter lilies. This bulletin is intended to supply specific information regarding the effects of controlled rooting temperatures on the growth of lilies.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE CULTURE AND FORCING OF EASTER LILIES

By Harold E. White

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The culture of Easter lilies for potted plants and cut flowers is an important source of income to Massachusetts florists. Since lilies are in greatest demand at Easter time, and florists' investments are usually highest at this period, it is imperative for growers to be familiar with the most efficient cultural methods. At present there is no uniformity of opinion as to what temperature is preferable for rooting of lilies. This bulletin presents the results of experiments with controlled temperatures on the growth of lilies, together with observations on other cultural factors.

Horticultural Importance of Lilies

Data taken from a survey of the United States Bulb Industry (4) indicate that between 1920 and 1931 the importations of all lily bulbs varied from 8,000,000 to 22,000,000 with average annual imports for that period of approximately 13,500,000.

Since 1931 the annual consumption of all lily bulbs has increased appreciably as shown by import figures secured from the Bureau of Entomology and Plant Quarantine at Washington.

	1935-36	1936-37
Japan	18,248,531	21,862,790
Netherlands	1,440,812	2,061,651
France	585,758	384,470
Bermuda	312,175	295,411
Total Imports	20,587,276	24,604,322

It is of interest to note that in six years annual average importations of lily bulbs increased from 13,500,000 for the period of 1920-31 to 22,595,314 in 1936-37. The quantity of bulbs used for forcing has been estimated by the trade to be about 85 percent of the total consumption.

Foreign and Domestic Production of Lily Bulbs

Types of lilies known by such commercial names as Giganteum (Gigs, among the trade for brevity), Harrisi, erabu, Creole, Vaughani, Howardi, Floridi, wonderbell, and Croft, are regarded as varieties of *Lilium longiflorum*. These varieties constitute what is commonly known in the trade as the Easter Lily group, as contrasted with garden or hardy types, such as *L. regale, auratum, speciosum, and candidum,* which are also used to a considerable extent by florists for forcing.

Japan exports to the United States 90 percent or more of all the lily bulbs imported into this country. From Japan come such varieties as *L. auratum, erabu, and speciosum,* besides *Lilium longiflorum giganteum,* which is grown in much greater quantities than any other variety. This is by far the most popular variety used for forcing purposes, particularly in the

United States at Easter time. These lilies are grown both in southern Japan where climatic conditions are favorable, and in the northern part of the island. Many florists prefer the southern-grown bulbs even though there seems to be no difference in the variety or type of plant.

Information on the culture of lily bulbs in Japan is rather meager but it appears that they are grown, for the most part, in small quantities by a large number of individual farmers rather than in large plantings. The assembling of the lily bulbs for market is apparently controlled by a few Japanese dealers and the American bulb importers make their contracts with them rather than with the growers.

Bermuda produces bulbs of a variety of Easter lily known as Harrisi which, while still being forced to a considerable extent by florists in the United States, is not nearly so popular as it was many years ago.

Holland exports a wide variety of hardy garden varieties of lilies. France is the chief source of supply for bulbs of *Lilium candidum,* better known as the Madonna Lily.

The domestic supply of lily bulbs in the United States is relatively small compared to the numbers imported annually from abroad. Garden or hardy types of lilies such as *L. Henryi, speciosum, tigrinum, regale,* and others are rather widely cultivated on a commercial scale over the country.

Griffiths (2), who has done much to promote interest in commercial development of lily culture in the United States, intimates that no geographical region is likely to be found agreeable to all varieties. The Pacific Northwest, the Atlantic Coastal plain, and the Gulf Coast regions are quite adaptable for many garden types. Tennessee and the Carolinas are also suitable cultural regions for lilies.

More attention is now being given to the production of Easter lily bulbs on a commercial scale, to supply the florists with forcing stock. One lily which has received considerable attention in this respect is a variety known as the Creole which is a strain of *Lilium longiflorum.* The Creole lily has been in cultivation for many years around New Orleans and is now being grown in considerable acreage in Mississippi and Louisiana as well as other southern localities. Strains and hybrids of the Creole lily have been tested at Waltham and were observed under forcing conditions to compare quite favorably with imported bulbs from Japan. In Florida a particular strain or hybrid form of the Creole is being grown under the name of floridi.

A selection of *L. erabu* originating in Oregon is known as the Croft lily.

Taxonomic relationship and classification of the many horticultural varieties and strains of Easter lilies are in need of clarification, but, at least for practical purposes, trade names are at present a satisfactory means of identification.

Bulb Size and Flower Count

Lily bulbs are classified according to their circumference in inches. A 7 to 9 inch bulb is preferred by a number of florists, but the growing tendency is to use 8-10 and 9-10 inch sizes. The larger bulbs will generally produce a greater number of buds but this is not consistently the case since the number of buds obtained from a lily plant does not depend entirely upon the size of the bulb. It would seem that in general the number of buds may be determined to a considerable extent by some inherent quality of the bulb itself as well as by many cultural factors prior to and during the forcing period. Some growers consistently obtain as many buds from 7-9 inch bulbs as others do from 8-10 or 9-10 inch bulbs.

The flower count on cold-storage lilies usually decreases with the increase in length of the storage period. For this reason, it is preferable to use the larger bulbs for forcing, particularly in late summer. Sometimes a smaller bulb may give an exceptionally good flower count even on cold-storage bulbs, but this is an exception rather than the rule if the bulbs have been stored for a long period of time.

Cultural Practices as Related to Forcing

The successful forcing of *Lilium longiflorum* for Easter, as of many other florists' crops, is dependent on the degree to which cultural conditions can be effectively manipulated. Considering the number of bulbs imported and the high degree of success of most growers, little can usually be said in criticism of the quality of the bulbs although seasonal conditions under which the lily bulbs are grown, temperature variations during transportation, degree of infestation with mites, presence of fungous diseases, and amount of mosaic carried by the bulbs may be contributory factors toward a certain amount of crop losses.

Experiences with a number of bulb dealers in this country indicate that they are cooperative and willing to make a reasonable adjustment and to assume a fair amount of responsibility when there are justifiable reasons for believing their products to be concerned with crop losses. The grower, on the other hand, often places too much responsibility for crop success or failure on the seeds, plants, or bulbs, and is prone to minimize the care of the materials prior to planting and the cultural attention given the crop during its growing period.

Experiences of a number of years, derived from consultation work with various growers on lily forcing troubles, indicate that florists who force from one to three thousand bulbs apparently have more trouble than a larger grower who forces annually twenty to forty thousand bulbs. A possible explanation for this is that perhaps the florist with a large amount of money invested in lily bulbs has planned the lily crop as a part of his system of crop rotation, whereas the smaller grower has tentative plans for his lilies to follow a certain crop space but if pinched for planting area he gets the bulbs in where and whenever he can. It requires approximately 18 to 20 weeks from the time of planting for the bulbs to reach the flowering stage. It is far better management to allow an extra two weeks, contingent upon weather conditions and the date of Easter, than to be a week late and have to resort to high temperature in order to flower the plants.

Pre-Planting Care of Bulbs

Upon receipt, cases of lily bulbs should be stored in a cool, dry place. Where a bulb storage cellar is not available, a well-ventilated potting shed or building will be quite satisfactory. If kept cool, the bulbs can be held several weeks before planting.

Temperature readings made on the packing soil around bulbs immediately upon arrival at Waltham were around 55° F. when the outside temperature was 70° F. This would indicate that with proper attention given to storage immediately upon arrival, the bulbs can be kept relatively cool even during an unexpected period of warm weather. With present efficient wholesale methods of handling bulbs, however, there is little or no need for the grower to be greatly concerned about storage facilities because the usual practice of dealers is to ship the bulbs at any time the florist is ready to plant them.

Potting Methods

The 7-9 inch bulbs are usually planted in 5 inch pots and the 8-10 or 9-10 inch are put in 5½ or 6 inch pots. Some growers plant the bulb rather deeply in the pot and fill the pot only one-half to two-thirds full of soil. Later on, after some root action has taken place and the bulb forms a shoot, the pot is filled with soil. Another method is to fill the entire pot with soil when the bulb is planted. There is, as far as known, no particular advantage of one method over the other. *Lilium longiflorum giganteum* is a stem rooting type of lily; therefore, the bulb should be planted deeply enough so that the portion of the stem where the roots develop is below the surface of the soil. The stem roots serve to anchor the plant more firmly in the soil and are assumed to aid in absorbing water and nutrients. Stem roots have never been removed to determine the extent of their nutritional function, but it has been observed that with very shallow-planted bulbs the plants bloomed just as well with the stem roots only partially covered.

Practice of Removal of Scales from Bulbs

The fleshy scales that make up the lily bulb function as storage organs for foods necessary to sustain the growth of the flower shoot and roots until sufficient leaves have developed to take care of the nutritional needs of the plant. On most lily bulbs there are a number of loosely attached, browned, shriveled, or broken scales. It is a common practice for some growers to remove a portion of the scales prior to planting.

Growers remove the outer, looser scales from bulbs presumably to prevent trouble from disease and mites. The value of such a practice is questionable so far as disease is concerned; it seems more reasonable to believe that removal of scales might render the bulbs more susceptible by leaving open wounds where infection might occur. Even though it has been intimated by some workers that the removal of scales and clipping the tips of others will hasten rooting of the bulbs, it is questionable whether the beneficial effect is proportional to the labor of handling a large quantity of bulbs in this manner.

The number of scales which may be removed from lily bulbs without injury appears to be determined by the size of the bulbs. A 7-9 inch bulb might be affected more by the removal of a certain number of scales than an 8-10 or 9-10 inch bulb having a greater number of scales. Pfeiffer (9) has noted that for 7-9 inch bulbs the average scale count per bulb for three seasons varied from 50 to 70, 66 to 75, and 45 to 65 respectively. The removal of 15 scales reduces the vitality of a 50-scale bulb more than it does with a 75-scale bulb.

In an experiment at Waltham using 7-9 inch bulbs, scales were removed from bulbs in different quantities to determine the effect on growth of the lily plants. In one group of bulbs, 10 to 12 scales were removed from each bulb in one lot; 15 to 18 scales from those in another lot; and 20 to 25 scales from those in a third lot. The removal of 10 to 18 loosely attached scales apparently had no harmful effect; but when 20 to 25 scales were removed from the bulbs, growth of the plants was considerably retarded.

Soils and Fertilizers

The preparation of any type of soil for flower culture is merely a question of either amending the nature of the soil to meet the desired cultural conditions, or regulating the cultural methods according to the nature of the soil. A soil which contains sufficient quantities of organic matter to insure adequate moisture conditions over a reasonable period of time and is properly balanced with fertilizers, is generally adaptable to a wider range of cultural practices than a soil which does not meet these requirements. The soil used for forcing lilies should be well drained yet contain enough fiber to maintain an even supply of moisture. With soils that are too porous considerably more attention will need to be given to watering the plants, particularly when high forcing temperatures are used. A good fibrous loam that will grow carnations or other flower crops can be used satisfactorily for lily bulbs. Lilies in experimental tests have been observed to grow equally well in soil amended with different quantities of well rotted manure, German peat, or sand. Even the soil in which the bulbs were packed for shipment, when used alone as a potting medium, has grown good lily plants.

Soils that are well supplied with plant food elements prior to the potting of bulbs should, as a general rule, need very little additional plant food during the forcing periods. The extent to which bulbs will need to be given fertilizer is dependent upon a number of factors. One, of course, is the degree of soil fertility prior to potting, and another is the nutrient condition of the bulbs themselves. Since the bulb is a storage organ for foods necessary to sustain a certain amount of growth of the plant, cultural conditions under which they are grown in the field will, in part, determine the forcing capacity of the bulbs. It is reasonable to assume that the size of the bulb should be a relatively good index in determining the degree to which the plants should be fed during the forcing period. Because of their greater food storage capacity, 8-10 and 9-10 inch bulbs should, on the average, require less fertilizer than smaller bulbs, such as 7-9 inch. However, some tests were made at Waltham in 1936-37 to determine to what stage a lily plant could be grown on foods stored in the bulb by planting 8-10 inch bulbs in sand without fertilizer. Bulbs so treated produced plants 12 inches tall with an average flower count of 4 per bulb, which was only slightly below the production of flowers by plants grown in soil. The results of this test indicate that added soil nutrients increase stem length and size of the blooms as well as developing all buds which have initiated in the bulb. It is often claimed by growers that some particular cultural method will result in a larger number of buds; but if only enough bud tissue is present in a bulb for four flowers, that bulb will not produce five or six flowers.

The stem length and growth of lily plants can be better regulated by planting the bulbs in a soil which is medium rather than high in nutrient content, and by applying at intervals a small quantity of fertilizer sufficient to maintain the desired rate of growth. The total number of feedings necessary should be determined more by the response and rate of growth of the plants than by any set rule. Assuming that the soil has an average medium nutrient content, four to six applications may be adequate. Overfeeding of the plants should be avoided because if it is found necessary to increase the growing temperature and humidity, the plants are likely to become too tall. The rate of growth and date of flowering are regulated by a number of cultural factors such as soil fertility, moisture, humidity, rooting and growing temperatures, and light.

Fertilizers may be applied in a dry or liquid form. If they are to be applied dry, a complete mixed fertilizer which is readily soluble in water should be used at the rate of about ½ teaspoonful to a 5 inch pot, or ¾ teaspoonful to a 6 inch pot. The most efficient way of feeding potted plants is to dissolve some quickly soluble form of nitrogen salt in water and apply it to the soil. For this purpose, sodium nitrate (15 percent nitrogen), calcium nitrate (15 percent nitrogen), or ammonium sulfate (20 percent nitrogen) may be used at the rate of 1 ounce in 2 to 3 gallons of water. A more concentrated form of nitrogen, such as Urea (46 percent nitrogen) may be used at the rate of 1 ounce to 7 gallons of water. When nitrogen fertilizers such as sodium nitrate are used, it is well to be sure that there is an adequate supply of phosphorus in the soil. If phosphorus is needed, a 3 to 4 inch potful of superphosphate may be added to each bushel of soil at potting time. In cases where it is necessary to supply phosphorus to the soil after the plants are growing, a more readily available form combined with ammonia nitrogen, such as Ammo-Phos (11 percent nitrogen and 47 percent phosphoric acid) at the rate of 1 ounce in 7 gallons of water, is quite satisfactory.

Soil acidity as it affects forcing of lilies is not of any great concern. In tests made at Waltham lilies grew equally well where the pH ranged from 5.5 to 6.5 If a proper balance is maintained between the plant food elements in the soil, the majority of plants appear to be adaptable to a wide range of soil reactions. As a sensible practice undoubtedly it is desirable to have the soil test about 6.0 to 6.5. Wiggin and Gourley (14) observed that as long as soils were not extremely acid or alkaline, many flowering plants proved to be quite adaptable to considerable variation in soil reactions.

Effect of Rooting Temperatures on Growth of Lilies

A review of the available literature on the forcing of lilies for Easter indicates that the general recommendation for florists is to use a low temperature of 50° to 56° F. for the rooting of lily bulbs. Laurie and Chadwick (6) recommend that lilies for Easter be left in a cool house until January, or started as soon as potted in a temperature of 54° to 56° F. Poesch (10) suggests that bulbs be placed immediately in a temperature of 54° to 56° F. and the temperature increased after they have been rooted. It is further observed that high temperature during the later growing period results in shorter stemmed plants. In neither case do these writers indicate that a comparison was made as to the effect of high and low temperatures on the rooting of lilies. Shippy (12) studied the effect of storage temperatures on Easter lilies in relation to flowering and observed that bulbs produced a greater number of blooms in the field when stored at warm temperatures than at cool temperatures. Hosaka (5) observed that subjecting bulbs of *Lilium japonicum* var. *insulare* for a period of 20 days to a temperature of 80° F., followed by a 40-day treatment at 55° F., stimulated root development and bud formation. When bulbs were held for 40 days during the rooting period at a temperature of 55° F., budding and flowering were very irregular and the results inferior to those obtained with a warm rooting temperature.

EXPERIMENTS WITH LILIUM LONGIFLORUM GIGANTEUM, Waltham, Mass. 1935-1937

Bulbs were rooted under controlled temperature conditions and in the greenhouse where temperatures were comparable to those used in commercial culture. The temperature controls were especially constructed cabinets containing approximately 20 cubic feet of space, with sides of double glass arranged to provide a one-inch air space, thus increasing insulation and admitting light to permit growth of plants. Splitwood blinds shaded the cabinets and control instruments from direct rays of the sun. Temperature was controlled by air thermostats of a bimetal type with a double mercury-tilt switch. Refrigeration was supplied by methyl chloride forced through coils hung from the top of the cabinets. An electric strip heater supplied heat which was circulated with a small electric fan. The temperature was controlled within a 3° differential when operated within 30° of the outside air temperature. No humidity control was provided, but pots of moist soil gave a variable relative humidity between 30 and 60 percent which averaged higher at cooler temperatures.

The controlled temperature cabinets used to root lily bulbs were operated at 42°-45° F., 52°-55° F., 62°-65° F., 70°-72° F., and 80°-82° F. In the greenhouse experiments, temperatures of 50°-52° F. at night and 55°-56° F. during the day were used to provide a cool rooting condition; while a night temperature of 60°-62° F. with a day temperature of 65°-68° F. provided a warm temperature condition. The temperatures in the greenhouses were regulated by thermostats.

Lily bulbs of 7-9 and 8-10 inch size were used in the experiments. The bulbs were allowed to remain in the cabinets and greenhouse rooting temperatures for a period of approximately six weeks, after which they were placed in a greenhouse and grown at a 60°-62° F. night temperature and 65°-70° F. during the day.

Root Growth.—Bulbs of *Lilium longiflorum giganteum* rooted much more quickly at a temperature of 60°-70° F. than they did at 52°-55° F. This difference in root growth due to temperature treatments was noticeable at the end of the six weeks rooting period and was still discernible at the end of 70 days from the date temperature treatments were started. At temperatures of 52°-55° F. root growth was poorer than at 60°-70° F. Bulbs did not root well at 80°-82° F. and the root systems developed by the bulbs were comparable to those on bulbs rooted at temperatures of 52°-55° F. The differences in rooting responses of the bulbs rooted at various temperatures as observed 70 days and 98 days from the date treatments were started are shown in Figure 1, A and B.

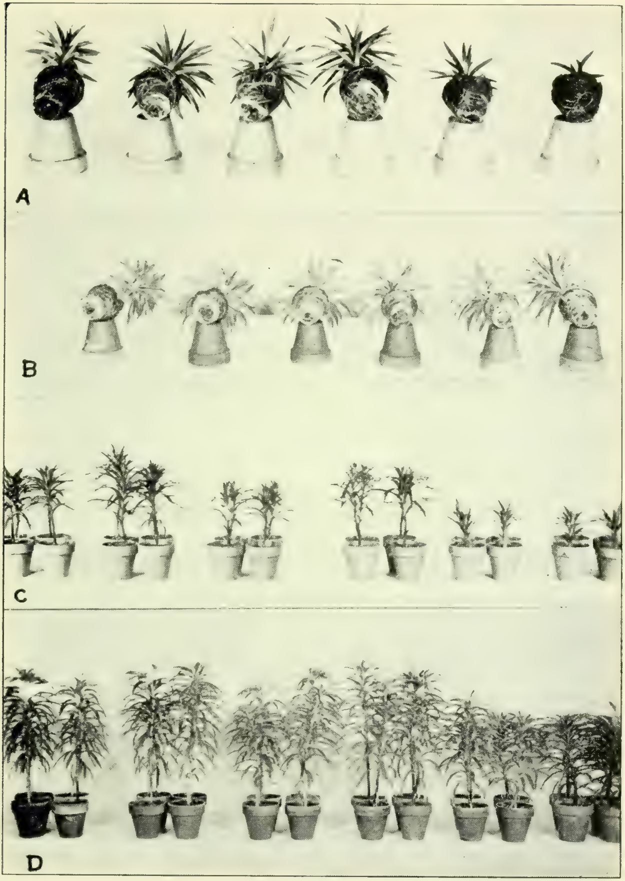

Figure 1. Effect of Rooting Temperature on Growth of Lilium longiflorum giganteum. Temperature treatments reading left to right: Cabinets, 80°-82° F., 70°-72° F., 62°-65° F.; Greenhouse, 62°-65° F., 52°-55° F., Cabinets, 52°-55° F.

A. Root growth 70 days from potting.
B. Root growth 98 days from potting.
C. Stem growth 70 days from potting.
D. Stem growth 98 days from potting.

(Note loss of foliage on plants from bulbs rooted at 80°-82° F.)

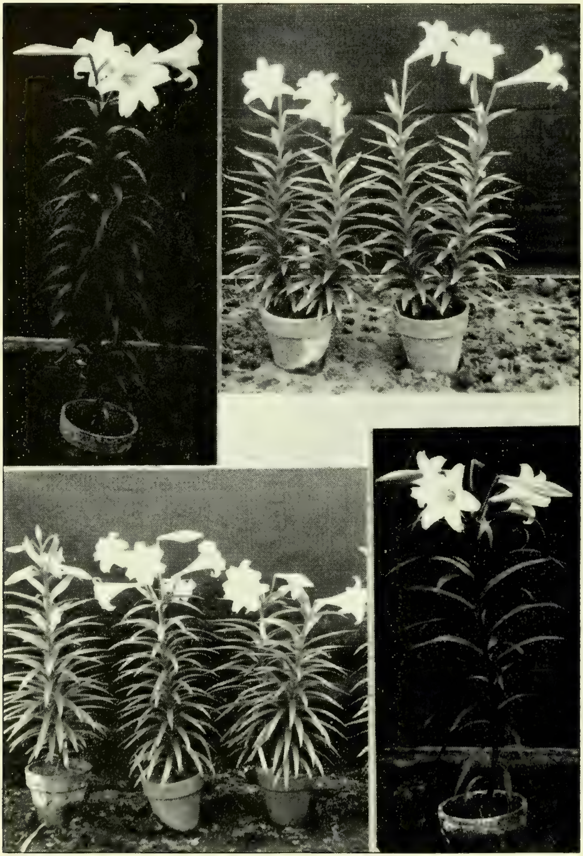

Figure 2. Commercial Varieties and Seedlings of Easter Lilies.

Upper left, Lilium Howardi; upper right, Lilium wonderbell; lower left, Waltham Field Station seedlings, a cross between Creole lilies and Lilium longiflorum giganteum; lower right, Lilium erabu.

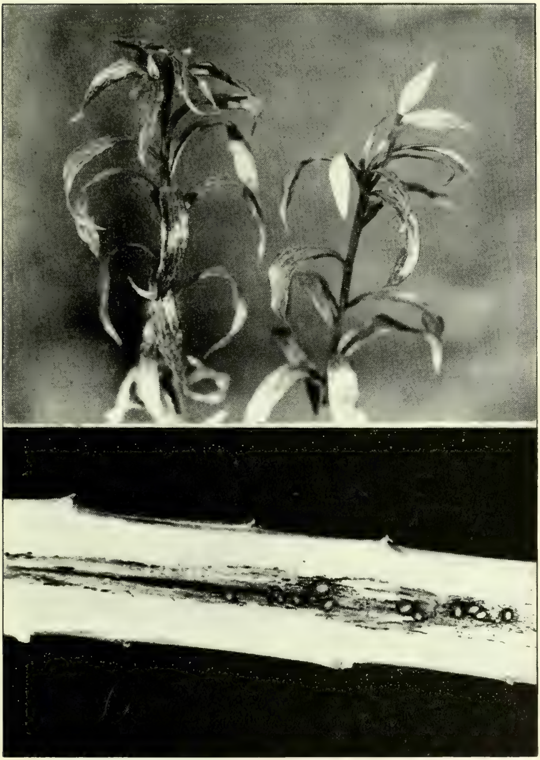

Figure 3.

Upper: Mosaic Disease of Lilies. Note curled and twisted condition of the leaves as well as mottled color of the foliage.

Lower: Lily Stem Tunneled by Bulb Mites. Note mites present in the stem tissue.

Stem Growth.—The higher temperatures at which lily bulbs were rooted not only affected root growth but also stimulated top or stem growth. At the termination of 70 days of growing, bulbs rooted at 52°-55° F. had an average stem height of 7.87 inches as compared to 11.00 inches of stem growth at 62°-65° F., and 13.30 inches at 70°-72° F. At a temperature of 80°-82° F. the rate of stem growth was retarded and plants developed long internodes as compared to a shorter type of internode produced by bulbs rooted at temperatures of 52°-55° F. and 62°-65° F. Plants grown from bulbs rooted at 80°-82° F. had a tendency to drop considerable foliage along the lower portion of the stems. See Table 1, and Figure 1, C and D.

TABLE 1.—INFLUENCE OF ROOTING TEMPERATURES ON RATE OF STEM GROWTH OF LILIUM LONGIFLORUM GIGANTEUM.

Waltham, Mass., 1936-37

Rooting Temperature	Average Height of Plants 70 days from Potting (Inches)
Cabinets	
52-55° F.	7.87
62-65° F.	11.00
70-72° F.	13.30
80-82° F.	11.87
Greenhouse	
50-55° F.	8.75
60-65° F.	13.37

Flower Production.—The number of flowers produced per bulb was slightly greater at 60°-65° F. than at 40°-45° F. rooting temperatures, as shown in Table 2. Flower production was the lowest when the bulbs were rooted at 70°-80° F. There was no perceptible difference in size or texture of blooms produced by bulbs rooted at the different temperatures.

TABLE 2.—RELATION OF ROOTING TEMPERATURES TO NUMBER OF BUDS PRODUCED BY LILIUM LONGIFLORUM GIGANTEUM.

Waltham, Mass., 1936-37

Rooting Temperature	Average Number of Bulbs Forced	Average Number of Buds Produced per Plant
Cabinets		
40-45° F.	25	4.00
50-55° F.	53	3.86
60-65° F.	53	4.86
70-80° F.	35	3.52
Greenhouse		
50-55° F.	53	4.22
60-65° F.	53	4.46

Blooming Dates.—The number of days required to bring Easter lily plants into bloom was reduced as the rooting temperatures were increased. The shortest period was approximately 100 days at a rooting temperature of 70°-80° F. as summarized in Table 3. With a rooting temperature of 40°-50° F., bulbs required about 150 days to bloom. The rate of development 98 days after potting is illustrated in Figure 1, C and D.

TABLE 3.—RELATION OF ROOTING TEMPERATURE TO LENGTH OF GROWTH PERIOD OF LILIUM LONGIFLORUM GIGANTEUM.
Waltham, Mass., 1935-37.

Rooting Temperature	Number of Observations	Average Number of Days from Potting to Bloom*
Cabinets		
70-80° F.	2	99-106
60-70° F.	6	116-138
50-60° F.	6	135-149
40-50° F.	1	151

*Date of flowering represents the time when the first flower opened on at least 50 percent of the plants.

Relation of Size of Bulbs to Earliness of Flowering.—The earliness of bloom was definitely influenced by the size of the bulbs. As shown in Table 4, 8-10 inch bulbs bloomed approximately 10 days earlier than the 7-9 inch bulbs at 52°-55° F., and 20 days earlier at 62°-65° F. Similar results were obtained under both controlled cabinet and greenhouse conditions.

TABLE 4.—SIZE OF BULBS IN RELATION TO DATE OF BLOOM OF LILIUM LONGIFLORUM GIGANTEUM.
Waltham, Mass., 1935-37.

Rooting Temperatures	Average Number of Days from Potting to Bloom	
	7-9 inch Bulbs	8-10 inch Bulbs
Cabinets		
42-45° F.	151	......
52-55° F.	145	135
62-65° F.	135	116
70-72° F.	......	106
80-82° F.	......	99
Greenhouse		
52-55° F.	145	133
62-65° F.	140	114

EXPERIMENTS WITH LILIUM ERABU AND LILIUM HOWARDI

The commercial varieties erabu and Howardi are generally believed to require low rooting temperatures for successful forcing (6).

As shown in Table 5, however, erabu bulbs forced at Waltham produced a slightly greater number of flowers and blossomed 16 days earlier when they were both rooted and grown at 62°-65° F. than when they were rooted at 52°-55° F. for 38 days before being grown at 62°-65° F. Plants from bulbs rooted at lower temperatures had much shorter internodes than those from bulbs rooted at higher temperatures.

The Howardi lily bulbs averaged only 3.2 and 2.7 blooms per plant which is too low a production for profitable forcing. A larger number of blooms was obtained from the bulbs which were rooted at 52°-55° F. However, the time required for flowering, figured from the potting dates, was 23 days longer for bulbs rooted at 52°-55° F. than for bulbs rooted at 62°-65° F.

TABLE 5.—EFFECTS OF ROOTING TEMPERATURES ON LILIUM ERABU AND LILIUM HOWARDI.

Waltham, Mass., 1937-38.

Variety	Temperatures		Average Number of Blooms	Average Number of Days from Potting to Bloom
	Rooting	Growing		
Erabu	52-55° F.	62-65° F.	4.1	114
	62-65° F.	62-65° F.	4.5	98
Howardi	52-55° F.	62-65° F.	3.2	125
	62-65° F.	62-65° F.	2.7	102

Effect of Artificial Light on the Flowering of Easter Lilies

The use of artificial illumination as a means of supplying additional light to growing plants has been extensively studied. In general, the practice of illuminating plants with electric lamps is a supplementary aid rather than a cultural method. Whether or not additional light can be profitably applied to a flower crop depends upon the natural response of the plants to such treatment and the cost of light application.

Flowering and growth of lily plants can be stimulated by the application of additional light as well as by the use of increased temperature. Laurie and Poesch (7) observed that six hours of additional light from 150-watt electric lamps were approximately equivalent to 70° forcing temperature and had ultimately the same effect. The cost of additional illumination was reported as 3 to 4 cents per pot. Their recommendations are that light treatments be applied for 36 days to 2 months prior to intended market date.

In addition to the direct effect of light itself, other factors which cause plants to vary in their response to light treatments are: first, the inherent peculiarities of the plant itself; second, the length of day (photoperiod); third, the intensity of the light; fourth, the stage of growth at the time light is applied; and lastly, the temperature at which the plants are grown.

In their studies on supplementary illumination of Easter lily plants (*L. longiflorum giganteum*), Greene, Withrow and Richman (1) in Indiana applied light and observed that the plants flowered earliest when irradiated for 20 days, starting 16 days after the bulbs were planted. These bulbs were planted December 15 and lighted with 500-watt lamps for a period of 5 hours each night under cultural temperatures of 65° F. at night and 70° F. during the day. The greatest decrease in number of days to flowering noted with 500-watt lamps was 8 days. Withrow (15) in later work recommends that at least 30 foot-candles or 200 watts of light be applied to lilies to hasten flowering.

Even though added illumination is given lily plants to hasten flowering, reasonable cultural temperatures should be provided. Roberts and Struckmeyer (11) observed that the response of plants to length of day was affected by temperature. They found that chrysanthemums under conditions of short or long day at cool temperatures produced sucker growth instead of stem growth; but with the same length of day, short or long, at warm temperatures stem growth was stimulated and sucker growth inhibited.

The usual method of applying light to lilies to hasten the blooming date for Easter is to use 200-watt lamps spaced 6 feet apart and suspended 2 to 2½ feet above the top of the plants. On benches 4½ to 5 feet wide, one 200-watt lamp will effectively illuminate approximately 27 to 30 square feet of bench space. A 14 inch R. L. M. dome reflector should be used with each 200-watt lamp. If the reflector is to be used at a future time with lower wattage lamps, an adaptor can be purchased to fit the smaller lamp.

The lily plants should be illuminated for a period of 5 to 6 hours daily, starting at sunset. In Massachusetts this will occur at approximately 4 p. m. in December and January, at 4.30 p. m. in February, and at 5 p. m. in March. A normal long day in summer has fourteen to fifteen hours of effective daylight while short days in winter may have eight hours or even less sunlight per day. In extremely cloudy weather in winter, the illumination of lilies for six to seven hours with electric lamps may not be sufficient to compensate for the greater lack of light during the day. Therefore, it may be found advisable to lengthen the daily period of artificial illumination one or more hours when such weather conditions occur.

The results of experimental work show that the flowering date of lilies cannot be hastened more than two weeks by the use of artificial light. Where a lily crop is definitely late, light should be applied six to eight weeks prior to Easter and reasonable growing temperatures maintained.

The number of lily plants a 200-watt lamp will illuminate depends on the spacing of the plants in a given bench area. Plants that are the most retarded should be placed directly under the lights and those more advanced toward the outer area of illumination. A 200-watt lamp operating for 6 hours will consume 1.2 kilowatt hours of electricity, which, at the rate of 4 cents per kilowatt hour, would cost between 4 and 5 cents per 30 square feet of bench area illuminated per night.

The use of light is merely an emergency method or cultural aid; it should not be expected to give miraculous results, particularly when the bulbs have been planted very late or improperly handled.

Easter Lilies from Seed

The production of lilies for flowers from seed is not a common practice among florists because it involves too long a time between seeding and flowering and too much labor. Excellent quality flowers can be grown from seedling lilies, however, particularly from hybrids. Under favorable conditions seedling lilies can be flowered in 14 to 16 months. Much better success will be had if they are grown in pots and shifted as needed, rather than in flats. The seedlings may be planted in the field but in view of the labor involved in lifting the bulbs in the fall, little is gained by this procedure. Lily seeds are slow and rather erratic in germinating, and when one is on the point of consigning them to the trash heap after considerable patient waiting, the seeds will often be found starting to germinate.

Seed of *Lilium philippinense* and its seedling strains, also an English variety known as White Queen, are available to those who are interested in the culture of lilies from seeds.

Results of forcing tests not only with the Field Station hybrids but with some one hundred hybrid lily bulbs from the United States Horticultural Station at Beltsville, Maryland, indicate that the domestic culture of lily bulbs for greenhouse forcing has possibilities. Selected hybrid seedlings from crosses between *Lilium longiflorum giganteum*, Creole lily, and erabu have been grown and flowered at Waltham under glass with remarkably good success. The quality and number of blooms produced by seedlings from crosses between *L. longiflorum giganteum* and Creole lilies, as shown in Figure 2, were comparable in many respects to those of the commercial varieties shown in Figure 2. Many of the hybrid Creole-giganteum seedlings averaged 5 blooms per bulb, with a number of the individuals producing as high as 6 flowers per bulb. Hybrid seedling lily bulbs harvested from the field on October 1 and air-dried for four weeks forced as well as those pre-cured for the same interval of time and then kept for four weeks in cold storage at 36° F. prior to forcing. One outstanding feature of lilies grown from seed is the response of such bulbs to greenhouse forcing conditions. The plants grow very rapidly and there is much less uneven growth of individual plants than with regular bulb stock.

Cold Storage of Cut Lily Flowers

The use of low temperatures under refrigerator conditions is confined chiefly to storage of cut flowers for relatively short periods of time and during transportation over long distances. It has even been suggested that the flower business would be better off if no refrigerators were used at all. Be that as it may, the following observations on the holding of Easter lily blooms may be of some interest.

Fifty or more stems of cut lily flowers were stored in containers with water in a refrigerated cellar on April 18 at a temperature of 38°-40° F. The lilies were in excellent condition with two and three blooms wide open on each stalk and buds in various stages of opening. These lily blooms were forgotten until discovered on June 6, and surprisingly the blooms were as crisp and fresh as the day they were cut, seven weeks previously. A number of stalks were taken out and the blooms which had been open seven weeks in cold storage kept well for four to five days under home conditions. The half open blooms developed sufficiently to be useful in design work, but less mature buds did not open satisfactorily. The remaining stalks of lily flowers were observed a week later and they were still in good condition. Just how much longer than eight weeks the blooms might have been kept is not known, for by accident the flowers were discarded before final observations were made.

Such a method of keeping lily blooms is not advocated as a general practice but might well be a means of salvaging what good blooms remain after Easter. As an emergency measure, a small retail grower who missed the Easter market could by this method hold many of his blooms for several weeks for use in design work.

Physiological Disturbances, Insect Pests, and Diseases

Tip-burn of Leaves.—Tip-burn of the leaves is a physiological condition which is brought about by unfavorable cultural conditions such as low humidity, high temperature, and deficient soil moisture. Lilies forced very rapidly under high temperature and humidity are likely to be more sensitive to changes in cultural conditions than are plants which, because they were grown more slowly, have a more hardened growth. In extremely cloudy weather the leaves of plants are likely to become filled with water, and with high humidity they are unable to get rid of this excess supply of water. Consequently, when a period of extremely bright weather follows, an abnormal loss of water from the leaves may result and cause leaf tip-burn or injury. The browning of leaf tips can also be caused by fumigants or spray materials.

When lily plants are fumigated with tobacco or cyanide, the foliage of the plants should be free from moisture and the fumigation should be carried on at a constant or rising rather than a falling temperature.

Splitting and Blasting of Buds.—Split and blasted buds are attributed to variations in cultural conditions at critical periods in the growth of the plants. Some of the factors that have been suggested are retarded growth, high forcing temperatures with improper humidity, sudden changes in temperature, and also a lack of sufficient roots on the plants to enable them to withstand forcing conditions. In three years of experimental study with lily bulbs only a few plants were observed to have split or blasted buds. Even when plants in different stages of growth were purposely changed from very warm to cool conditions and vice versa, there was no noticeable injurious effect from such treatments.

Aphids.—Aphids or green fly and bulb mite are the two most common pests of lilies.

Aphids can be controlled by fumigation with tobacco and by the use of contact insecticides such as nicotine sulfate, pyrethrum, and derris (rotenone) spray materials. Plants should be sprayed early enough in the day to permit the foliage to dry quickly, in order to avoid the danger of foliage injury from the spray.

Mites.—Mites are usually present to some degree on all lily bulbs, but the amount of injury to the bulbs depends upon their abundance. The wounds made by mites feeding on the scales, particularly near the basal plate, generally result in the destruction of the root system of the plants. In severe infestations mites often tunnel up through the stem from the base, stunting the growth and causing the stems to break off or rot near the soil (Figure 3).

Frequently the feeding of mites on bulbs results in wounds which in turn are attacked by fungi and bacteria, generally causing the bulbs to rot.

Mites are most active under conditions of high humidity and temperatures of 60°-80° F. Under cool temperature conditions the mites become less active but are able to survive the unfavorable environment by changing into a resistant form known as the hypopus stage.

Some control is afforded by dipping the bulbs for 10 to 15 minutes in 40 percent nicotine sulfate, diluted at the rate of 1-400 which is equal to 1 ounce in 3 gallons of water. This treatment is reliable only in cases of light infestation of mites. If bulbs are relatively heavily infested, the most effective control measure is to immerse them in hot water at a temperature of 122° F. for 10 minutes. Lily bulbs should be examined carefully for pests or diseases and necessary treatments made before planting.

Mosaic.—The most common disease of Easter lilies is mosaic, so named because of the mottled or chlorotic color pattern produced on the leaves of infected plants (Figure 3). A certain amount of this disease generally appears in most lilies but *L. speciosum, auratum, formosum*, and *longiflorum giganteum* are most commonly affected.

The causal factor of lily mosaic as well as that of most virus diseases of plants has not been clearly determined. It has been suggested that the virus diseases are chemical or hereditary in nature rather than pathological. The term "'virus" is used to designate those diseases causing mosaic or yellows.

Symptoms of mosaic disease in lily plants may appear as a chlorotic or mottled condition of the foliage, curled or twisted leaves, blindness, and a dwarfing or stunting of the whole plant. Flower buds may be split or distorted in shape or may fail to open.

A very virulent form of mosaic is known as yellow flat disease (3). This stunts the growth, curls or twists the leaves, and gives a flat rosette-like appearance to the plants.

Mosaic is spread from plant to plant by aphids, and infection which occurs in the field is transmitted to the bulbs. So far as is known, the virus which causes lily mosaic is similar to the one causing aster yellows in that the virus must pass some time in the body of an insect before it can be transmitted to a healthy plant. Certain types of mosaic disease of tomatoes and tobacco can be transmitted from one plant to another mechanically during such operations as pinching and pruning of the plants. Mosaic disease of lilies is seldom spread to any degree under greenhouse forcing conditions, particularly if insect infestations are promptly and properly controlled. However, when lily plants growing close together in the greenhouse become heavily infested with insects, the mosaic disease can be readily transmitted by the insects from one plant to another.

Bulbs infected with mosaic do not generally show external symptoms sufficiently distinct to differentiate those that are diseased from those that are not. Tilford (13) and Ogilvie (8) state that bulbs infected with the yellow flat disease may be smaller than normal, flat, compact in shape, and inclined to split. As a rule, the loss of lily plants from mosaic disease under forcing conditions is relatively low. In fact, the average losses due to insects, diseases, and unfavorable growing conditions may be conservatively estimated at only 3 to 5 percent.

Summary

Between 18,000,000 and 21,000,000 lily bulbs are imported annually into the United States from Japan alone for greenhouse forcing purposes. *Lilium longiflorum giganteum* is the most popular commercial type of lily forced for Easter.

Most failures with an Easter lily crop are, to a considerable degree, attributable to improper cultural conditions rather than to the quality of the bulbs.

Experimental tests at Waltham showed that the removal of 20 to 25 scales from 7-9 inch bulbs reduced the vitality of the plants.

Lilies grew equally well in soils with and without the addition of such materials as manure, peat, or sand, and they are not particularly sensitive to soil acidity conditions. Soils properly prepared for bulbs need relatively few applications of fertilizer during the forcing period.

The height of lily plants can be regulated by careful use of fertilizers and attention to forcing temperatures.

Lilium longiflorum giganteum bulbs rooted better at temperatures above 60° F. than at temperatures below 60° F., and the rooting temperature influenced the subsequent rate of stem growth. Lilies rooted at a temperature of 80°-82° F. required approximately 100 days to bloom, compared to 140-150 days for lilies rooted at 52°-55° F. Bulbs rooted at 60°-70° F. produced slightly more blooms per plant than those rooted at temperatures below 60° F.

The 8-10 inch bulbs bloomed approximately 20 days earlier than the 7-9 inch bulbs.

Erabu lilies bloomed 16 days earlier and produced a greater number of blooms per plant when rooted and grown at 62°-65° F. than when rooted at 52°-55° F.

Electric lamps may be used satisfactorily to hasten the date of blooming of Easter lilies.

Cut lily blooms were held successfully for a period of eight weeks in a storage temperature of 38° to 40° F.

Tip-burn of lily foliage may be caused by fumigation, spray materials, or improper cultural conditions; and blasted or split buds may result from sudden changes in temperature, poor root development, and low humidity. Heavy infestation of mites on the bulbs is frequently a contributing factor in losses of Easter lily plants during forcing. Mosaic disease of lilies is carried in the lily bulbs and may be destructive to the plants. The average loss from all these causes, however, is relatively low.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 377 October 1940

Inheritance of Broodiness in Rhode Island Reds

By F. A. Hays

This is an attempt at a sounder basis for the elimination of broodiness in poultry through the selection of breeding stock and to discover whether sex-linked genes are concerned.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

INHERITANCE OF BROODINESS IN RHODE ISLAND REDS

By F. A. Hays,
Research Professor of Poultry Husbandry

INTRODUCTION

The broody instinct is a normal inherited character in domestic chickens. This character was partially eliminated in the Mediterranean breeds during the last half of the nineteenth century so that they were considered to be non-sitters. The general purpose breeds and Asiatic breeds were almost universally broody at that time. Published data on the percentage of broodiness in different breeds are limited.

Kirkpatrick and Card (1917) reported that 13.6 percent of the White Leghorns in the fifth Storrs Egg Laying Contest became broody. Goodale, Sanborn and White (1920) pointed out that the foundation stock of the Massachusetts Station Rhode Island Reds was 89.6 percent broody; after five years of breeding, the percentage of broody birds was reduced to 18.9. Hurst (1925) reported 4.8 percent of the birds broody in a flock of 84 White Leghorns. Hays and Sanborn (1926) reported 27.35 percent broody birds in Rhode Island Red flocks averaging 200 eggs, and the number of broody periods fell to a mean of less than two. Hays (1933) attempted to develop a non-broody and an intense-broody line of Rhode Island Reds. After nine generations of breeding, the lines showed 72.66 percent and 20.46 percent, respectively, of the females non-broody in the first laying year. In a high fecundity line, Hays (1939) reported a decrease in the incidence of broodiness from 86.31 percent in 1916 to 2.16 percent in 1937.

The mode of inheritance of broodiness is somewhat controversial at present. Punnett and Baily (1920), Goodale, Sanborn and White (1920), Hays (1923), and Warren (1930) all present data to indicate that the broody instinct is inherited on the basis of dominant autosomal factors. On the other hand, Roberts and Card (1933) observed that reciprocal matings between White Leghorns and Dark Cornish indicated that a sex-linked gene was involved. It is possible that, in the crosses used by Roberts and Card, the use of White Leghorn sires may have deferred the onset of broodiness in a large percentage of the hybrid daughters to the second laying year or later.

Degree of broodiness as measured by the number of broody periods appears to be inherited as well as the presence and absence of the broody instinct, according to Hays (1933). Selection to reduce broodiness had no effect upon the mean length of the non-productive period associated with each broody period, which remained at about fifteen days through twenty five years of breeding, as reported by Hays (1939).

Broodiness may be artificially produced, according to Riddle, Bates and Lahr (1935), by injecting prolactin from the anterior lobe of the pituitary into non-broody hens. Burrows and Byerly (1936) found a higher content of prolactin in the pituitaries of broody hens than in those of laying hens or males. These workers also observed a greater amount of prolactin in pituitaries of males and females in genetically broody lines than in non-broody lines.

Broodiness affects the physiological state of the individual bird, according to unpublished data collected on Rhode Island Reds at the Massachusetts Station by Dr. H. D. Goodale. In a study including 21 hens, the daily body temperatures were recorded throughout the period to discover possible changes during broody cycles. As a rule there was a temperature drop from the mean of about 106.5 degrees to about 105 degrees for from three to five days following the cessation of laying associated with a broody period. The mean daily body temperature of six non-broody laying hens from December 8 to February 6 was slightly above 106 degrees. Daily temperature records were taken on five sitting hens from September 8 to October 5. Here the range in temperature was from 103 to 107.5 degrees, with a mean of about 105.5 degrees.

Scope of This Report

The present study includes the birds hatched from 1929 to 1938, inclusive, in our non-broody and high fecundity projects. The data include 72 sires and 210 dams, with a breeding performance record based on 1767 daughters.

These data are considered from three standpoints relative to the inheritance of the broody instinct: first, inherited degrees of broodiness; second, deferred broodiness; and finally, possible sex-linked inheritance of the broody instinct.

INHERITED DEGREES OF BROODINESS

It is a well-known fact that the number of broody periods varies widely among individuals, and may range from one to eight or more in the first laying year. Hays (1939) pointed out that, in a flock of Rhode Island Reds bred to reduce broodiness, the mean number of broody periods in each individual fell from 3.5 to 1.1 in the 18-year period from 1916 through 1933. In the same period, the percentage of broody individuals fell from 86.31 to 5.19. Since the mean length of the non-productive period associated with each broody period has remained constant at almost fifteen days, it is obvious that any quantitative measure of degree of broodiness must be based on the number of broody periods.

The behavior of daughters from dams showing different degrees of broodiness is recorded in table 1. All daughter records include only the first laying year.

Group 1 dams were kept for but one laying year and had but one broody period. Of the daughters of such dams, 72 percent were non-broody, 10 percent were broody once, 7 percent were broody twice, and 11 percent were broody three or more times. Based on their own behavior and on the behavior of their daughters, the group 1 dams appear to represent a low degree of broodiness.

Group 2 dams had been broody twice in their first year of laying. Only 28.26 percent of their daughters were non-broody and more than 39 percent had three or more broody periods. These dams were decidedly inferior to the group 1 dams.

Group 3 dams belong to a more intensely broody group, as they had shown three or more broody periods in their first year. Only 9.76 percent of their daughters failed to go broody, and 63.41 percent behaved like the mothers with respect to the number of broody periods. As breeders, the group 3 dams are inferior to the two previous groups.

Group 4 dams were kept for only one laying year and did not exhibit the broody instinct. They produced 89.29 percent non-broody daughters, 7.14 percent broody once, 2.23 percent broody twice, and 1.34 percent broody three or more times.

Group 5 dams were tested for two full laying years and did not exhibit the broody instinct. Such dams should be more nearly correctly classified than were group 4 dams, which were kept for only one laying year. The group 5 dams produced 92.81 percent non-broody daughters and the majority of their broody daughters had but one broody period. They may therefore be considered the most desirable group of breeders thus far considered.

Group 6 dams were trapnested for three laying years and did not exhibit broody behavior. The daughters of these hens were 91.12 percent non-broody, the degree of broodiness being essentially the same as for the daughters of group 5 dams. The data on groups 5 and 6 appear to indicate that the phenotype of hens with respect to broodiness can be determined with a high degree of accuracy from trapnest records over two years or more.

TABLE 1.—DEGREES OF BROODINESS IN DAUGHTERS OF DIFFERENT TYPES OF DAMS.

Dam's Group*	Number of Dams	Total Number of Daughters	Daughters							
			Non-Broody		Broody					
					Once		Twice		Three times or more	
			Number	Percent	Number	Percent	Number	Percent	Number	Percent
1	11	100	72	72.00	10	10.00	7	7.00	11	11.00
2	4	46	13	28.26	12	26.09	3	6.52	18	39.13
3	12	41	4	9.76	4	9.76	7	17.07	26	63.41
4	34	224	200	89.29	16	7.14	5	2.23	3	1.34
5	60	459	426	92.81	21	4.58	9	1.96	3	.65
6	69	721	657	91.12	41	5.69	13	1.80	10	1.39
7	16	128	100	78.13	11	8.59	10	7.81	7	5.47
8	4	48	35	72.92	5	10.42	2	4.17	6	12.50
Total or Mean	210**	1767	1507	66.79	120	10.28	56	6.07	84	16.86

*Dam groups were made up as follows:

1. Broody once in first laying year.
2. Broody twice in first laying year.
3. Broody three or more times in first laying year.
4. Not broody in first laying year.
5. Not broody in first two laying years.
6. Not broody in first three laying years.
7. Broodiness deferred to second laying year.
8. Broodiness deferred to third laying year.

**Of the 210 dams, 108 had broody daughters and 102 had no broody daughters.

Dams that are not broody until the second laying year (group 7) may be considered to be less intensely broody than those going broody in the first laying year. Group 7 dams may be compared with group 1 dams for indications of possible genetic differences. The only evidence to indicate a possible genetic difference in the two groups of dams lies in the fact that 11.00 percent of the daughters from group 1 dams were broody three or more times, compared with 5.47 percent of the daughters from group 7 dams.

There were four dams (group 8) that did not exhibit the broody instinct until their third laying year. These dams had the same percentage of non-broody daughters as the group 1 dams; and among the broody daughters, the proportions broody once, twice, or three or more times were essentially the same. From the standpoint of the number of broody periods in their daughters, the two groups of dams do not appear to differ.

In general, the data in table 1 indicate that degree of broodiness as measured by the number of broody periods depends upon heritable factors. Rather conclusive evidence on this point is the fact that, as the number of broody periods in dams increased, the percentage of daughters showing three or more broody periods increased for dams of groups 1, 2, and 3. Dams that were broody once in their pullet laying year (group 1), dams that were broody first in their second laying year (group 7), and dams that were broody first in their third laying year (group 8) showed about the same breeding behavior with respect to the number of broody periods in their daughters; indicating that the time of onset of the broody instinct during the life of the individual may not affect the intensity as measured by number of periods. Dams that are phenotypically non-broody may be selected with a good degree of accuracy at the end of two laying years, as indicated by groups 4, 5, and 6. These data serve to emphasize the importance of first reducing the degree of broodiness and following this by selective breeding to eliminate the instinct from the flock through the use of aged tested breeding stock.

Breeding Behavior of Broody Hens

There were 7 dams with only a first-year production record that exhibited the broody instinct. Each of these dams produced some broody daughters in a total of 56, indicating dominant inheritance. There were 15 broody dams that had two complete production records and 133 daughters. Thirteen or 86.67 percent of these dams produced some daughters with the broody instinct, and two had no daughters going broody in their first laying year. A total of 19 broody dams was kept for three full laying years and had 203 daughters that completed one year of laying. Sixteen or 84.21 percent of these dams produced some broody daughters and three had no broody daughters.

This group of 41 broody dams includes only individuals that had at least three daughters that completed the first laying year. There was a total of 392 daughters tested. More than 85 percent of these tested dams had some broody daughters; and those with no broody daughters may not have had an adequate test because of too few daughters or because of deferred broodiness in daughters.

DEFERRED BROODINESS

The term "deferred broodiness" may be used to indicate the delayed appearance of the broody instinct in the second laying year or later. Goodale, Sanborn and White (1920) recognized the problem of deferred broodiness in Rhode Island Reds but presented no data. Punnett (1923) also referred to deferred broodiness in Leghorn-Langshan hybrids. From the point of view of the breeder who is attempting to eliminate broodiness, this delayed appearance of the broody instinct is of considerable importance. Naturally the question arises of the accuracy of selecting hens for the non-broody phenotype after one year of laying or more.

In the total of 210 dams used in the breeding tests, 47 exhibited the broody instinct while they were under observation. In table 2 the amount of deferred broodiness is recorded.

TABLE 2.—TIME OF ONSET OF BROODY INSTINCT IN TESTED DAMS.

	Tested Dams	
	Number	Percent
Broody in first year	27	57.45
Broody in second year	16	34.04
Broody in third year	4	8.51
Total number broody	47	

The broody instinct was exhibited by 57.45 percent of the dams during their first laying year. Broodiness was deferred to the second year in 34.04 percent of the dams and to the third year in 8.51 percent. The 27 dams that became broody in their first laying year are shown in groups 1, 2, and 3 of table 1, and 47.59 percent of their daughters were non-broody. Group 7 dams, whose broodiness was deferred to their second laying year, had 78.13 percent non-broody daughters. The group 8 dams, whose broodiness was delayed to the third laying year, had 72.92 percent non-broody daughters. Although the data are limited, there is reasonable evidence that when the broody instinct appears in dams in their first laying year, their daughters are twice as likely to exhibit the trait in their first year as daughters from dams with broodiness deferred to the second or third laying year. Quantitatively, at least, dams with deferred broodiness may be superior as breeders to those broody in their first laying year.

In the group of 210 dams tested, only 22.38 percent exhibited the broody instinct while they were under observation. According to table 2, only 57.45 percent of these broody dams were discovered by one year of trapnest records; but when two laying-year records were available, 91.49 percent of the phenotypically broody dams were discovered; and when the records covered three years, probably 98 or 99 percent of such dams would be discovered. From these observations it is clearly evident that the broody trait will persist in a flock until all females are retained to such an age as will bring out all deferred broodiness. At the same time males must be tested through their daughters from aged mothers, and all such daughters must be retained for a long period to discover deferred broodiness. There is no evidence reported that any flock has as yet been entirely freed of the broody instinct.

EVIDENCE REGARDING SEX-LINKED INHERITANCE OF BROODINESS

Although no evidence has been presented from this Station to indicate sex-linked inheritance for broodiness, it is desirable to test these data for possible sex-linkage.

Dams that were not broody themselves and that had produced no broody daughters during their first breeding year were considered to be partially tested dams. Seventeen males were mated to these tested dams. Eight of the males or about 47 percent produced some broody daughters. In the total of 210 dams in table 1 that were given a breeding test, 108 or 51.43 percent had some broody daughters. These facts indicate that essentially the same percentage of sires and dams transmitted the broody character to their daughters.

Selection of Breeding Males and Females on the Broody Behavior of Their Sisters

Breeding males are often selected on the basis of the broody behavior of their sisters. Breeding females, on the other hand, may be selected on both their individual broody behavior and the behavior of their sisters. Table 3 supplies evidence on the effectiveness of selections based on sisters' behavior as far as the broody instinct is concerned, and compares the transmissibility of the broody trait by males and by females selected on the same basis.

Table 3.—Breeding Behavior of Sires and Dams.

	Sires		Dams	
	Number	Average Percentage of Broody Daughters	Number	Average Percentage of Broody Daughters
With broody sisters	38	32.06	111	28.66
With no broody sisters	34	10.90	95	12.36

The 38 sires with broody sisters had families with an average of 32.06 percent of broodiness. The 34 sires with non-broody sisters had families with an average of 10.90 percent of broodiness.

There were 111 breeding females with broody sisters. The daughters of this group showed a mean family broodiness of 28.66 percent. From 95 dams that had no broody sisters, the mean family broodiness in the daughters was 12.36 percent.

These figures indicate that selection on the family basis to eliminate broodiness is effective, and that sires and dams selected on the same basis transmit the broody instinct equally.

Breeding Behavior of Full Brothers and Sisters

Nineteen groups of full brothers and sisters were tested to discover the percentage of broodiness in their daughters for the first laying year. These groups include 24 brothers and 26 sisters. A group is made up of one brother and one or more of his sisters, or of more than one brother and one or more of their full sisters. The mean percentage of broody daughters based on the mean of families is recorded in table 4.

TABLE 4.—BREEDING BEHAVIOR OF FULL BROTHERS AND SISTERS.

Group No.*	Percentage of Broody Daughters	
	Brothers	Sisters
1	37.4	25.0
2	50.0	20.8
3	0.0	43.0
4	14.2	10.0
5	4.2	12.5
6	50.0	40.0
7	100.0	100.0
8	18.0	20.0
9	25.0	8.0
10	18.0	25.3
11	37.5	14.5
12	5.0	20.0
13	0.0	0.0
14	7.6	12.5
15	0.0	3.3
16	0.0	0.0
17	8.5	13.5
18	0.0	0.0
19	10.4	3.5
Mean	20.31	19.57

*A group is made up either of one brother and one or more of his full sisters, or of more than one brother and one or more of their full sisters. The total number of brothers was 24 and of sisters, 26.

If there were a sex-linked factor and one or more autosomal factors concerned in the inheritance of broodiness, it being a dominant character, brothers would be expected to transmit the character to a higher percentage of their daughters than would their sisters.

The data in table 4 show that in seven of the groups broodiness was transmitted to more daughters by the brothers, while in eight of the groups the reverse was true, and in four groups the brothers and sisters transmitted equally. Such breeding results would be anticipated on the basis of autosomal factors by the law of chance, but not on the basis of sex-linked factors.

Correlation Studies

The coefficient of correlation may be used to throw further light on the question of sex-linked inheritance of the broody instinct. The correlation between sires' sisters and sires' daughters in percentage of broodiness should be higher than between dams' sisters and dams' daughters in percentage of broodiness, if sex-linked genes are operating.

These correlations were calculated in the following manner: The percentage of broodiness in the sisters of each of 72 sires was paired against the percentage of broodiness in the daughters of each of his mates. The percentage of broodiness in the sisters of each of 206 dams was also paired against the percentage of broodiness in the daughters of each dam. No sires or dams were included unless they had at least three full sisters and three daughters with a complete annual record. Regression was found to be linear in both cases. The constants arrived at were as follows:

	Sires	Dams
Number	72.	206.
Mean percentage broodiness in sisters	49.65	46.34
Standard deviation	±32.17	±31.91
Mean percentage broodiness in daughters	54.12	50.03
Standard deviation	±33.35	±33.43
Coefficient of correlation	.6906 ± .0364	.7119 ± .0341

There was a marked similarity in the mean percentage of broodiness in the sisters of sires and of dams, as well as in the percentage of broody daughters from sires and from dams. The two coefficients of correlation are of almost identical magnitude, which again suggests the absence of sex-linked genes for the broody instinct.

Phenotypes of Daughters from Broody Hens

A study was made on the daughters of 41 broody dams that had enough daughters to give something of a clue to the proportions that were broody and non-broody. According to the AC theory, these dams must have carried both genes A and C because they exhibited the broody instinct. Since selection had been carried on for a long time to eliminate broodiness, it is probable that most of these dams were Aa Cc in genetic makeup. Theoretically, when no selection has been practiced, there would be nine different genotypes of males with respect to genes A and C.

Table 5 shows that 14 of the 41 dams had 25 percent broody daughters, indicating that many of the sires used were pure recessives (aa cc). There were 6 dams with about ⅜ of their daughters broody, and these may have come from sires heterozygous for a single dominant gene. Ratios of 50-50 could come from males that were pure for one dominant factor, but there was not a single dam with a family of such proportions. Doubly heterozygous males and females when mated should have 9/16 of their daughters broody. Table 5 suggests but four such matings. There were 12 dams with all their daughters broody. Such proportions could come either from males or from females homozygous for both genes A and C or from broody hens that carried one dominant gene in homozygous state mated to males that were homozygous for the second dominant gene. The appearance of 5 families of non-broody daughters from broody mothers is probably due to inadequate numbers of daughters and to deferred broodiness in the daughters. In general the data in table 4 indicate that few sires used were homozygous for either dominant gene. There is also evidence that the sires used were freer from broody genes than were the broody dams whose daughters were included in table 5.

Table 5.—Phenotypes of Daughters from Broody Hens.

Percentage of Broody Daughters (Class)	Number of Families
0	5
25	14
38	6
50	0
56	4
100	12
	41

SUMMARY

Breeding tests on the inheritance of the broody instinct in Rhode Island Reds were carried through a ten-year period using 72 sires and 210 dams which produced 1767 daughters. Evidence was secured on inherited degrees of broodiness, on the problem of deferred broodiness, and on possible sex-linked inheritance of broodiness. A number of deductions were made from this study.

1. Degree of broodiness as measured by the number of broody periods in the first laying year is inherited.

2. Broodiness depends in inheritance on two complementary dominant genes A and C; neither appears to be sex-linked.

3. Dams exhibiting the broody character in their first laying year had about twice as many broody daughters as dams in which the broody instinct did not appear until the second or third laying year.

4. In the data presented, 57.45 percent of the broody dams were broody in their first year, 34.04 percent were not broody until their second year, and 8.51 percent were not broody until the third year.

5. Deferred broodiness greatly retards progress in breeding to eliminate the broody trait.

6. The complete elimination of the broody instinct appears to be very unlikely, at least in the American breeds.

7. No evidence was found to indicate sex-linked factors in the inheritance of the broody instinct.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

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Annual Report

For the Fiscal Year Ending November 30, 1940

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

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FITZPATRICK, WILLIAM H., Horticultural Manufactures
‡GARLAND, WILLIAM, Entomology
‡GILGUT, CONSTANTINE J., Botany
GLAZIER, LYNN R., Dairy Industry
GUTOWSKA, MARIE S., Poultry Husbandry
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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION — 1940

INTRODUCTION

F. J. Sievers, Director

Research, as first inaugurated in our agricultural experiment stations, had as its primary, if not its sole, objective a direct service to the farmer in the development of a more efficient production of agricultural products. While this objective appealed to the imagination of those delegated the responsibility of directing the activities of the experiment stations, its interpretation required modification so that the program of investigation could include also the problems of the farm home and, more recently, the problems of the entire consuming public where these problems were related to or influenced by the products of agriculture.

In the last several years, and especially during the period of depression when the nation was confronted with several paradoxical situations in its economy, it became evident that a critical evaluation of all public service agencies was in order. As a result of such a study the conclusion became self-evident that, while the problems over which the farmer could and might exercise control had been quite adequately served, there was not the same organized interest in serving the agricultural industry as a whole. With this study came a realization that the problems of the agricultural industry were not the concern of the farmer solely but were more especially a matter of public concern, and that some public agency was needed to give these problems emphatic and intelligent consideration. For this service the state agricultural experiment stations were naturally considered best qualified.

The acceptance of this responsibility, however, will affect not only the extent but more especially the nature of the work. By degrees, this change in service will be reflected in the projects which furnish a basis for these Annual Reports. Not only will experiment stations hereafter be required to furnish the technical or experimental evidence essential to the solution of problems of the farmer; they will need to become the source of that leadership which will keep the agricultural industry on a sound basis. The experiment stations should be relied upon to furnish the protection necessary to make sure that the practices developed on the farm in the interest of profit, or even of subsistence, are not operating to the detriment of the agricultural industry or the permanency of agricultural production, because it is recognized as unsound to depend upon the farmer in a matter of such wide general interest.

It is hoped that this report may contain some evidence that the Massachusetts Station is taking this new responsibility seriously.

DEPARTMENT OF AGRICULTURAL ECONOMICS AND FARM MANAGEMENT

A. H. Lindsey in Charge

Enterprise Relationships and Farm Organization on Selected Farms in Massachusetts. (C. R. Creek.)

Costs and Returns of Growing Beans for Canning in Massachusetts. Supervised records of costs and returns were kept by 22 of the 54 farmers who grew green and wax canning beans for the first time in 1940. Acreage was contracted with each grower and the price established at $2.50 per hundredweight for grade A beans and $1.00 per hundredweight for grade B. These 22 growers had 10.75 acres of wax and 30.9 acres of green pencil pod beans, which yielded 2371 pounds and 4528 pounds per acre, respectively. For all the farms that kept records, 82 percent of the wax beans and 80 percent of the green beans were grade A. Since price was determined entirely upon grade, the wax beans were delivered for $2.227 and the green beans for $2.196 per hundredweight or $2.20 for all beans.

Cash costs included expense for seed, fertilizer, lime, dust material, rent, taxes, tractor and truck fuel, and hired labor for growing and harvesting. Family labor at 20 cents per hour and 20 cents per bushel for picking, and use of horses and machinery were added to these expenses to obtain total or farm costs for the enterprise. For all farms the cash cost was $74.75 per acre, $1.88 per hundredweight of beans, or 49 cents per bushel. The farm cost was $83.70 per acre, $2.11 per hundredweight and 55 cents per bushel. On 18 of these farms there was a net gain over cash costs, ranging from $1.31 to six cents per hundredweight; but only nine farms showed a gain over total farm costs, which ranged from 70 to 10 cents per hundredweight. Two farms had very large losses in cash and farm costs because of high growing expenses and low yields.

The seven farms that had the lowest costs per hundredweight of beans had much greater yields of higher quality beans on a larger acreage than the seven farms with highest costs. Farm cost was $1.84 and $3.22 per hundredweight and cash costs $1.75 and $2.52 respectively for these two groups. The low-cost farms showed a gain of 37 cents per hundredweight or $18.85 per acre over farm costs and 46 cents or $23.20 gain over cash costs. The bean enterprise was a losing proposition on the seven high-cost farms, with a cash loss of 40 cents per hundredweight or $8.50 per acre or a loss of $1.10 per hundredweight or $23.40 per acre when total farm costs were charged. Failure of the wax bean crop, low yields, and poor quality were the chief reasons for the losses on these farms.

Beans can be grown for canning in Massachusetts despite high labor and land costs if the farmer knows how to grow beans. The net return per acre will be smaller than in a year of good market prices, but a return is guaranteed by the contract if the beans can be grown for less than the established price. Commercial vegetable growers on large farms produced these beans for a profit in 1940 although many small growers lost money.

Grass Silage on Massachusetts Dairy Farms. The most common use of grass or hay silage in 1939 was to supplement summer pasture during the drouth in July and August. It was also used instead of green feed in the summer, as a supplement to corn silage in winter feeding, and in place of corn silage on some farms. Records on 72 farms throughout the state showed that 10,600 tons of molasses silage were made from 1477 acres of various crops with a yield of 7.2 tons per acre. This silage was fed to 3994 cows at the annual rate of 2.6 tons per cow.

Mixed clover, alfalfa, and grasses were cut on 18.6 acres per farm for 31 farms to make 38 percent of the grass silage produced on these farms. Legume hay (clover and alfalfa) was cut on 23 of the farms with 14 acres each to make 22.5 percent of the total volume. Oats, wheat, rye, and barley were harvested green for silage on 37 farms with only 7.5 acres per farm to make 18.7 percent of the grass silage production. These small-grain crops were combined with vetch and peas, or millet and sudan grass with soybeans on 19 farms for 12.5 percent of the total tonnage from 9.5 acres per farm. Perennial grasses and millet and sudan were a small proportion of the entire crop although the yield of the two latter crops was highest at 8.5 tons per acre. Legume hay and mixed hay produced over seven tons of silage per acre, with some farmers obtaining as much as 10 tons.

Grass silage was made chiefly on institutional farms and the larger private dairies where special loaders and blowers could be purchased. On 15 farms both items were purchased at a total cost of $600 while other farm operators bought cutters at $425 or loaders at $170. The special grass cutter and blower was considered by these dairymen to be more essential to efficient operation than the grass loader.

Most frequently mentioned advantage of grass silage was the fact that unfavorable weather caused no delay in putting up the crop. Milk production was maintained during the summer of 1939 by feeding grass silage, and some dairymen stated that production was increased over corn silage in winter feeding. Other points which were mentioned were less waste in coarse first cutting of grasses, higher quality hay from second crop, continuous use of land with a rotation of annual crops for grass silage, less expensive than green feed and more uniform distribution of labor during the summer when grass silage was produced.

Some disadvantages had to do with poor quality of feed because the grass was cut too late, and disagreeable odors from the molasses silage which were probably due to spoilage because insufficient molasses was used. Extra help and special equipment costs were other drawbacks.

Vegetable Farming in Bristol County, Massachusetts, in 1939. (Norman R. Urquhart—in cooperation with the Bureau of Agricultural Economics of the United States Department of Agriculture.) Cash expenses of growing vegetables and operating the farm business used up all the cash income from sales of produce and other sources on 22 commercial vegetable farms in Bristol County for the 1939 crop year. Low yields and low prices combined to make this one of the most unprofitable seasons in recent years. Adjustments in inventories and the charge for family labor produced a $300 loss per farm in farm income. Interest on investment increased the loss to $692 in labor income.

One-third of the farms that were the most profitable had a net cash return and farm income of more than $1000 per farm and a labor income of $485. However, the seven farms with greatest losses had cash expenses of $1080 more than receipts. The acreage of vegetables per farm was almost equal in these two groups, but the yield of all crops was 16 percent larger and prices were 11 percent higher on the more profitable farms. Labor cost was higher per acre on the latter farms because of harvesting work, but labor return was 22 cents per hour compared to three cents on the unprofitable farms. The average labor return for all farms was only 10 cents per hour. In 1939, the farms that made money produced several kinds of vegetables. This probably reduced the loss from the four or five very unprofitable crops in this area. Ten diversified farms with dairy and poultry enterprises in addition to vegetables and potatoes showed net returns that were much greater at $1453 per farm. Of this, $1157 was income from the livestock enterprises above feed and replacement costs.

The ten most important vegetable crops on the basis of total acreage on these commercial farms were sweet corn, tomatoes, iceberg lettuce, green beans, peppers, celery, spinach, cucumbers, cabbage and wax beans. These ten crops occupied 82 percent of the total acreage and accounted for 80 percent of total vegetable sales.

For the crop year 1939, 13 of the 22 commercial farms had greater cash incomes than cash expenses of operating the farms. Four farms had over $1000 of net cash return which ranged from a high of $2342 to a loss of $4432 for all farms. On 10 farms, after family labor and depreciation were charged, the farm income was greater than expenses. Only six farm operators had a labor income as payment for their labor and management of the farm for the year.

Suggested farm plans for the reorganization of three low-income market garden farms have been prepared. Small fruits, strawberries and raspberries, have been substituted in the crop plan for the vegetables which were most unprofitable. A small poultry enterprise has been added to the farm business for the period from October through March to provide additional farm income. Plans were also made to increase the amount of family living from the farm through the crop and livestock enterprises.

These plans were made in an attempt to appraise the recommendations of the Rural Policy Committees on the basis of facts obtained in the economic analysis of these farms. The present crop and livestock systems were compared with the suggested systems to show the effects of the recommended changes in the choice and combination of enterprises. The plans cannot be evaluated here since they have not been entirely completed or approved.

Labor Saving Methods and Techniques on Vegetable Farms. (C. R. Creek and Richard Elliot.) Data were obtained on the time required to harvest and pack early iceberg lettuce on 10 farms in the Dighton area in June 1940. The most common method of harvesting consisted of two operations: cutting and trimming the heads; and packing into crates in the field. Each cutter usually took three rows, cutting all heads that were ready and placing them on the stump of the plant with the butt end up. Then the heads were packed into crates by other workers who followed the cutters. A crew of five men on one farm cut 22 crates (18 heads) of lettuce per hour per man. This lettuce was packed at the rate of 28 crates per hour for each packer.

In another system of harvesting lettuce two men cut and trimmed heads which were tossed to the packer who kept a crate nearby. Four crews of three men cut and packed 16 crates of lettuce per hour per worker. The fastest crew did 20 crates and the slowest did 13 crates per hour. A third system was used where one man cut and packed the heads in one operation. A small crew of two men cut and packed 17 crates each in an hour on poor cutting.

Packing-shed operations were of two types: one where the packed crates were washed, paper and ice applied, and slats nailed on; and the repack system, where heads were packed into crates after being brought from the field in flat boxes. The most efficient packing-shed system was a line where packed crates were washed in a tub under a spray, removed to a table and ice applied, then pushed along and paper put on, after which the slats were nailed on the crates. In these operations on iceberg lettuce the work was done more efficiently where each man had a particular job to do or where the principle of division of labor was applied.

Methods and techniques in harvesting and packing tomatoes were studied in five market areas. Trellis tomatoes that were sold in baskets on the Boston market were picked and packed with less effort and in less time than the ground type of tomatoes in one-half boxes for the same market. In other areas trellis tomatoes were sold in bushel boxes, one-half boxes, and fruit baskets. Time required for packing varied greatly according to quality of the tomatoes, method of packing, layout of the packing shed and individual differences in workers. Here again, the "line system" was most efficient, the tomatoes being run out on an endless belt from the wiping machine and packed by workers stationed on both sides. Packing from boxes or from trays was generally slower and more tiresome than the "line system."

Celery harvesting in the field and packing shed operations were checked again in 1940. Many of the farm systems which were studied in 1939 have been rearranged and the celery was bunched and packed more rapidly this year. Harvesting and packing of carrots, cabbage, and cauliflower were studied on one or more farms to determine more efficient and easier methods.

Competitive Factors Influencing the Supply of Market Milk and Cream in Massachusetts. (A. A. Brown, J. Elizabeth Donley, and Mabelle Booth.) Attention during the past year has been devoted to refining the information on the density and location of production in the Springfield milkshed and preparing the manuscript for publication.

The shed was divided into fourteen areas or sections within which marketing characteristics were similar. Total production in these areas ranged from an average daily volume of 3,578 pounds to 18,136 pounds, a ratio of about 1:5. Since this difference might have been due to differences in the size of the areas, total production was reduced to pounds per square mile, or density of production. Here there was a range of from 34 to 180.9 pounds, with a ratio of 1:5.3 between the lowest and the highest density. This variation in density of production was attributed to variation in two factors: the density of farms (per 10 square miles) within the area and the average size of farm in each area. A correlation analysis showed that density of farms was about twice as significant as size of farm in explaining variation in density of production.

Simplified, the shed is made up of several geometric figures. The main area is a triangle with its base in northern Connecticut and its apex in Sunderland, Massachusetts. On the right side of the triangle is a square including the Gilbertville, Ware area. To the northwest is a non-adjoining broad arc-shaped belt. In addition to these sections is a rectangular one in southeastern Vermont and an irregular one just over the Massachusets line in eastern New York.

The extremes in production were in the arc-shaped belt; to the lower left in the Berkshire Hills, deliveries per day per dairy were small, 125–

128 pounds; in the center and to the upper right they were relatively large, 226–287 pounds. Comparatively high production was characteristic also of the square on the right of the triangle, 220–224 pounds. A scale of production, intermediate to the extremes, was characteristic of the belt contiguous to and surrounding the market, 190–214 pounds. Production in the angles of the triangle tended to average about the same and was moderately light, 162–169 pounds.

An Analysis of Selected Merchandising Practices in the Fruit and Vegetable Industry. (A. A. Brown, Sargent Russell, and Mabelle Booth.) A study of apple prices on Washington Street Wholesale Market was made for 1934–35 and 1935–36. In studying the relationships between various factors which supposedly affect wholesale apple prices in New York City, no significant relationship was found other than that which existed because of normal seasonal variations of the factors. Stating it another way, when the normal seasonal variation was removed from the factors which affected price, no further relationships existed. The factors studied were temperature, weather (precipitation and degree of cloudiness), receipts (total as reported by Market News Service), and sales (figures for two companies from which records were obtained).

Correlations between price and temperature, weather, receipts, and sales without the removal of seasonal variation, were:

Temperature	.7427
Weather	.4284
(0 was clear)	
(10 cloudy or rain)	
Receipts	.8023
Sales	.6026

An investigation was also begun on the Cambridge Regional Produce Market. A study of this cooperative farmers' market was undertaken to determine the extent to which it has failed to come up to expectations; and the causes for such failure.

The degree of failure depends on the measure used. Certainly if one uses the regularity with which the market corporation has paid the interest on its obligations, the undertaking has failed 100 percent. If one uses the number of wholesalers and jobbers who have moved from the old market districts to the new as a measure of failure, the result is also 100 percent. If the degree of patronage by so-called large buyers—the chain stores and out-of-town jobbers—is the measure, the extent of failure is still complete. These premises were, however, the original ones upon which success was supposed to depend. In addition to them, of course, was farm patronage and in this quarter there has been both failure and success, and the achievements are all the more remarkable. Complete records during the first five years of the market are not yet available.

During the 1940 season for July 1 to October 25, inclusive, a period of 82 market days, 548 different farmers used the Cambridge Regional Produce Market. Only 36 of the total, however, were on the market for more than half the entire season. Equally extreme was the appearance of 183 users who sold on the market but once.

A preliminary analysis indicates that the majority of market users were small-scale farmers. They accounted for approximately 75 to 95 percent of the sellers on any one day, and had fifty packages on the load.

At the peak of the season on September 20, 140 farmers' trucks were on the market. The low point was on July 16 with 17 trucks. The market was most heavily patronized on Friday night, with the other days of the week in the following order: Monday, Wednesday, Thursday, and Tuesday.

DEPARTMENT OF AGRONOMY

Walter S. Eisenmenger in Charge

Tobacco Projects. (Walter S. Eisenmenger and Karol J. Kucinski.) It has been found that when plants of high lignin content are grown during the year preceding tobacco, the succeeding crop of tobacco is more likely to be affected by the so-called brown root-rot. The ligneous material, instead of being itself a specific cause of trouble, apparently encourages a class of decomposing organisms which are conducive to injury of the crop.

With the maturity of any seed plant the lignin content increases. During the past two years twelve different crops were sown at three different periods at about four-week intervals. The earliest plantings of these crops were completely ripe; the second, less ripe; and the third, still in the succulent stage when freezing weather came.

When tobacco was grown the following year on these variously treated plots, it was apparent that the tobacco grown after the completely mature crop was inferior to tobacco grown after the less mature crop, and the tobacco grown after the most immature plants was the best.

In another phase of this investigation tobacco was grown following a large number of plants. These various crops arrange themselves in the following descending order based upon the three-year average of the crop index of tobacco grown in rotation with them: sea weed (application), squash, horseweed, red top, ragweed, Jerusalem artichoke, gladiolus, carrots, sweet clover, buckwheat, cabbage, turnip, wheat, tomatoes, rye, Kentucky blue grass, millet, orchard grass, alfalfa, peppers, Sudan grass, sorghum, and red clover. In general the various crops ranked about as in other years in their effect upon yield and quality of tobacco.

The Lignin and Methoxy Content of Some Common Crops. (Walter S. Eisenmenger and John W. Hurdis.) It has been known for a long time that during the active period of decompositon of plant tissue containing large percentages of lignin, a retardation of growth and subsequent economic loss result with some crops. This presence of large quantities of lignin seems to interfere rather seriously with the tobacco crop.

Twelve different plants were chosen for study: Jerusalem artichoke, barley, buckwheat, corn, millet, oats, rape, rye, sorghum, Sudan grass, timothy, and tobacco. Samples were harvested at three different periods of maturity: first, when the crops were in a stage of rapid vegetative growth; second, when they were nearing maturity, being in the dough stage of seed development; and third, when they were mature.

As the plants approached maturity, there was an increasing carbon content, which, in conjunction with a decrease of total nitrogen, brought about a widening of the carbon–nitrogen ratio. With maturity, an increase in the methoxy content of the plants and in the methoxy content of lignin accompanied their increasing lignin content, while the total extractives and ash decreased. Those components which are most resistant to the action of bacteria and fungi are the ones which increase with maturity.

When tobacco followed these plants, the yields were lowest, both in quantity and quality, on those plots where the preceding crop had been allowed to mature.

The Absorption by Food Plants of Chemical Elements Important in Human Nutrition. (Walter S. Eisenmenger and Karol J. Kucinski.) If certain chemical elements are added to the soil in abundance, they are taken in by some kinds of plants in amounts larger that the normal growth and metabolism of the plants require. This is sometimes referred to as "luxury consumption" of elements. Other elements, however, are taken into the plants only in amounts needed. In this experiment, lettuce and cabbage were grown on a soil to which the cations, sodium, potassium, magnesium, and calcium, and the anions, chlorine, iodine, bromine, sulfate, and phosphate, were added separately to plots in quantities known to be far in excess of normal plant requirements, but not in sufficient quantity to be toxic.

The analyses show that the intake of all cations was substantially increased and that the increases of magnesium and potassium were greater than those of calcium and sodium. Thus, magnesium and potassium are much more nearly in the "luxury consumption" class than either calcium or sodium.

Phosphorus was increased in the roots about twice as much as in the tops, while the greatest increase of bromine and iodine was in the tops. Bromine and chlorine showed the highest percentage increases of any of the elements studied. Sulfur was increased substantially in both tops and roots of lettuce but not in cabbage. Cabbage is noted for its sulfur content; but sulfur is not a "luxury consumption" element, and the cabbage takes in only its normal amount regardless of the presence of an excess of the element in the soil.

The Intake by Plants of Elements Applied to the Soil in Pairs Compared to the Intake of the Same Elements Applied Singly. (Walter S. Eisenmenger and Karol J. Kucinski.) Results of other experiments have shown that the application of elements to soil tends to increase their quantity in the plant. In this experiment it was decided to study the intake by plants of elements added two at a time to the soil in quantities known to be excessive but not toxic. The materials used supplied calcium, potassium, and sodium at the rate of 250 parts per million of soil, and lithium at the rate of 100 parts per million. Lithium is exceedingly toxic; therefore it was added several months before seeding.

This study is in its initial stages, but analysis of cabbage, celery, and lettuce plants indicates that when sodium and calcium salts were applied together to soil, the calcium intake of the plants decreased. Similar results were obtained when potassium was added with calcium, but the percentage intake of potassium increased. Plants can tolerate lithium only in small quantities; but when potassium and lithium were added together to the soil, the intake of lithium was decreased. When cabbage plants were grown in soil treated with both potassium and sodium, the potassium intake was definitely decreased, which indicates that sodium can apparently replace potassium in plant nutrition.

Magnesium Requirements of Plants. (Walter S. Eisenmenger and Karol J. Kucinski.) Various species of plants have been grown on an area known to be deficient in magnesium. On the basis of foliar observation in the field it has been possible to separate the different species into two groups according to their apparent tolerance to magnesium deficiency. This classification is as follows:

Tolerant

- Alfalfa
- Apple
- Asparagus
- Beans
- Beets
- Blueberries
- Carrots
- Gladiolus
- Hollyhocks
- Lettuce
- Millet
- Peas
- Rhubarb
- Rye
- Soybeans
- Strawberries
- Sudan Grass
- Sweet Potatoes
- Swiss Chard

Not Tolerant

- Buckwheat
- Cabbage
- Cauliflower
- Corn
- Cucumber
- Eggplant
- Grapes
- Mangels
- Muskmelons
- Okra
- Peaches
- Peppers
- Potatoes
- Pumpkins
- Radish
- Rape
- Rutabagas
- Spinach
- Squash
- Sunflower
- Tobacco
- Tomatoes
- Turnip
- Velvet Leaf (***Abutilon avicennoe***)
- Watermelon

Chemical analyses of the various plants have shown that when only magnesium was added to the soil all plants increased in magnesium, while their calcium content was generally decreased. Experience has shown that magnesium is more easily introduced into plant tissue than calcium when additional amounts are added to soil. When magnesium and calcium are added to the soil together, the intake of both elements may be decreased.

Calcium applications hastened the maturity of certain cucurbits. Determination of sugar in raspberries showed that magnesium applications tended to increase the sugar content while application of both magnesium and calcium produced raspberries with the highest sugar content.

The Relative Toxicity of Certain Ions and the Function of the Calcium Ion as an Antagonist as Indicated by Soybean Roots. (Walter S. Eisenmenger and Plese Corbett.) It has been recognized in agricultural practice that elements used to stimulate plant growth or as fungicides and insecticides may leave residues in the soil which tend to act as poisons to the plants if applied in sufficiently large quantities. However, if these same elements are applied in moderate quantities, they may be beneficial.

Seedlings were grown in single salt solutions of calcium nitrate, copper sulfate, lithium carbonate, manganese sulfate, magnesium sulfate, and zinc sulfate. Since the anions of these salts have been found not to influence growth to any appreciable extent, the cations are the factors to be considered. Each of the cations, Ca++, Cu++, Li+, Mg++, Mn++ and Zn++, was found to be toxic in single salt solution; but the calcium ion in the form of $Ca(No_3)_2$ when placed with any one of the other single salt solutions overcame the toxicity of the medium to soybean seedlings. Over wide ranges of concentrations, the mixed solutions were less toxic than any of the single ion solutions.

Th Effect of the Calcium Ion on the Development of Soybean Seedlings and the Antagonism of This Ion to Arsenic, Boron, and Selenium Ions. (Walter S. Eisenmenger and Elvin T. Miles.) Farmers in certain regions have in recent years suffered partial loss of their crop because of relative scarcity of boron in the soil. This deficiency of boron was seemingly augmented by the addition of lime to the soil. It seems that when small amounts of boron are used on the soil to produce more normal plant growth the application of calcium will reduce the efficiency of the boron. This action of lime is not unlike that experienced when the calcium is used to overcome the toxic effect of overdoses of boron. Also in certain sections of the country the residues of arsenic from applications of sprays over a long period of time have been found to retard subsequent growth of annuals.

In an experiment designed to show growth of seedlings of soybeans in single salt solutions of boron, arsenic, and selenium, it was found that 1 p.p.m. of arsenic, 1.5 p.p.m. of boron, or 4 p.p.m. of selenium in aqueous solution produced a toxic reaction. In the presence of a neutral calcium salt, however, arsenic produced toxic effects only when the arsenic was present at the rate of 2 p.p.m. The toxic action of boron and selenium was also depressed by the presence of a neutral calcium salt. On the other hand it also holds true that the ions of arsenic, boron, and selenium will counteract the toxic action of single salt solutions of neutral calcium ions.

The Effect of Arsenious, Arsenic, and Antimony Oxides on Soil and Plant Growth. (Walter S. Eisenmenger and Hrant M. Yegian.) Pot culture studies under greenhouse conditions on the effect of arsenious, arsenic, and antimony oxides on Merrimac fine sandy loam and subsequent crop growth are being continued. Five successive crops, barley and buckwheat alternating, have been grown in the same pots during 1939 and 1940, and the lightest applications of arsenious and arsenic oxides (500 p.p.m. and 250 p.p.m. respectively) are still toxic to barley, and 1500 p.p.m. of arsenious oxide and 2,000 p. p. m. of arsenic oxide are toxic to buckwheat.

It was found that by returning sufficient amounts of buckwheat and barley tops to the pots arsenic toxicity could be overcome. A photograph of the fifth crop, buckwheat, grown in pots treated with arsenious oxide shows the value of organic matter in overcoming the arsenic toxicity very clearly. (Page 57.)

The antimony oxide treatment did not affect the yields of barley or buckwheat, and the soil was not injured even temporarily by the heaviest application (2000 p.p.m. antimony oxide).

Sunflowers and Their Possibilities. (Karol J. Kucinski and Walter S. Eisenmenger.) After the encouraging results obtained last year, the experiment was continued. Although the season was exceptionally late this year, sunflowers were planted on the 15th of May and grew to maturity, forming exceptionally large seed heads.

From the standpoint of seed production, fertilizer tests with sunflowers show that apparently they are not very heavy feeders. Doubling the application of fertilizer increased the yield of seed only about 5 percent. The best plots yielded about one ton of good seed to the acre. Seedings of one seed per hill every 18 inches in 36-inch rows proved to be better than two seeds per hill in 36-inch check rows. Two seeds per hill 18 inches apart produced very thin, weak plants which lodged so badly after wind storms that the crop was almost a complete failure. The two pictures on page 56 show comparative results obtained with the two systems of planting.

When sunflower plants were used for silage, as high as 19 tons per acre were obtained, comparing favorably with the yield of corn. If the sunflower plants were ensiled while their leaves and stalks were still green, cattle seemed to relish the silage and thrive on it.

Soil Conservation Research Projects. (Karol J. Kucinski and Walter S. Eisenmenger.)

A Survey of Erosion Problems Arising from Changes in Land Use. During the past year a detailed study has been made to find out whether the increasing potato acreage in Massachusetts has encouraged soil erosion problems. Many acres of old sod and pasture land have been plowed under within the past two or three years. Most of this new potato land is located on the sloping hillsides in the western part of Massachusetts. It is quite evident that this change in land use is resulting in the rapid decomposition of soil organic matter which has been accumulating for the past generation. The soil is exceptionally fertile at present and lends itself to large-scale field operations. If the potato crop is harvested very late in the fall and no cover crop is used, the soil erodes very readily with an appreciable loss of topsoil. It is felt by some that if this soil erosion is permitted to go on without any precautionary measures being taken for its prevention, the present high yields of potatoes cannot be maintained because of loss of organic matter and fertility of the top soil. It is deemed advisable, therefore, to encourage potato growers to practice soil conservation methods such as winter cover cropping and terrace and contour farming of their hillsides.

The Relation between the Rate of Wind Erosion and the Principal Factors Affecting it. In one phase of this investigation a detailed study was made of the wind erosion at the Cape. The sand areas found at the extremity of Cape Cod are approximately 6,000 acres in extent. Most of these areas, and especially those enclosing Provincetown Harbor, were originally forested but have been extensively devastated within historic time. As far back as 1714, and especially in 1826, extensive reclamation programs were initiated to stabilize these sand areas at the Province Lands. These early attempts were not too successful because woody plants were planted in the shifting sand without any previous introduction of beach grass to prevent the sand from moving away from the newly planted trees.

Today, various methods are used with great success in controlling the shifting sands and establishing permanent vegetative cover over the dunes. On very active sand dunes, branches of native pine are spread on the northwest side of the dune covering the "blow side" or "live side" of the dune. These branches act as a barrier which reduces the velocity of the wind and a shelter which catches beach grass seed. This beach grass seed, which is plentiful, germinates and the grass starts to establish itself during the next season. Not until the beach grass is well established is it desirable to make any tree plantings. Usually after two or three years the beach grass will spread itself sufficiently over the sand to prevent any further occurrence of serious "blow outs." When this stage has been reached, pine trees can be planted safely. It is the common practice to plant in the early spring when there is plenty of moisture in the sand three- to five-year-old pine trees in rows about three feet apart in either direction. Various species, such as *Pinus sylvestris, P. mughus, P. austriaca*, and *P. rigida*, have been used effectively in establishing permanent cover over the dunes. The Austrian pine has been found preferable to the Scotch pine (*P. sylvestris*) for this region, since it seems to withstand the cold winters experienced at the Cape better than any other tree that has been tried.

In certain localities where the wind tends to blow out the embankments of roads it is expedient to sod with hog cranberry or beach grass a continuous strip two or three feet wide, parallel to the edge of the road. In some instances it has been found practical to spread a thick layer of native grass hay on the active wind-blown road embankments. This acts as a protective mulch for germinating the seed that is present in the hay or that is blown in.

Seeds of such native plants as sand peas, sumac, and Scotch broom, when sown broadcast on the sand in places where the wind is not too severe, germinate and produce a very desirable cover. To a lesser extent transplantation of bayberry shrubs can be useful in forming a protective marginal planting and windbreak where the wind has started to expose roots of previously planted trees. On the other hand, the beach plum, which is quite common, should not be encouraged since it is a host to many insects which are harmful to the more desirable types of trees.

The photograph on page 57, taken at Wellfleet, shows the characteristic way in which hog cranberry is adapted for controlling slope erosion on the sandy hills and roadside embankments at Cape Cod.

Trials with Improved Strains of Hay and Pasture Species. (W. G. Colby.) Nursery trials and small-plot experiments carried on for the last three years with several hundred strains of grasses and legumes indicate that some of these strains have definite merit and should be given wider trials over the state. Included in this group of superior plants are strains of Timothy, Orchard Grass, Meadow Fescue, Perennial Ryegrass, and Medium Red Clover.

Timothy. The following selections obtained from Professor Morgan W. Evans at Wooster, Ohio, gave superior performance:

F. C. 11,901: This is a very early-maturing strain, vigorous in growth, moderately leafy, and producing a good aftermath growth if weather conditions are favorable. It reaches the "bloom" stage about the 20th of June.

F. C. 15,167: This selection matures about a month later than F. C. 11,901. It is a dark green, leafy strain which produces a good yield of hay but not much aftermath.

Orchard Grass. The aggressive growth habits of orchard grass together with its early maturity have been some of the undesirable features which have hindered its more general use. The following improved strains have overcome, to some extent at least, some of these undesirable features.

Aberystwyth S. 37: This is a very leafy strain which produces a dense vigorous growth. Relatively few seed stalks are produced and these reach maturity about ten days later than the seed stalks of commercial strains of orchard grass. The use of this strain both in hay and pasture mixtures seems promising.

Finnish Commercial: A strain of orchard grass obtained from a commercial seedsman in Finland shows promise as a hay type. It does not grow as tall as native commercial strains but it produces a dense, dark green growth, is much more leafy, and matures a week later.

Meadow Fescue. Svalöf's Early Meadow Fescue has been the most promising strain of this species. Although a little earlier than is desirable, this strain is the only one tested which thus far has shown a complete immunity to leaf rust. During the 1940 season the rust infestation on all other strains was severe and seriously affected the yield.

Perennial Ryegrass. Although perennial ryegrass may never become an important hay or pasture grass in Massachusetts, several of the strains tested were superior to those now available commercially. The strain O.A.C. No. 1 from Dr. McConkey at Guelph, Canada, and the strain E. F. 79 and Otofte from Denmark should be included in this group.

Red Clover. Of the many strains of medium red clover tested, three obtained from Dr. E. A. Hollowell of the U. S. D. A. grew particularly well. These were F. C. 22,655 (Central Corn Belt Blend), F. C. 22,586 (Illinois Red Clover), and F. C. 30,124 (Indiana Red Clover). A number of strains of foreign origin made a vigorous initial growth and suffered no winter injury but were severely attacked by leafhoppers. For this reason alone it was necessary to discard practically all strains of foreign origin.

Ryegrasses as Green Manure Crops. (Hrant M. Yegian and W. G. Colby.) The relative value of three varieties of ryegrass as green manure and winter cover crops following onions is being studied. The species which have been grown are briefly described as follows:

Domestic ryegrass (*Lolium sp.*) is a moderately winter-hardy species which is already being used as a cover crop by many vegetable growers. From 50 to 60 percent of the plants will survive the average winter; so unless the crop is completely turned under in the plowing operation, volunteer plants may interfere with the cultivation of the subsequent crop. If planted by the middle of August and plowed under by the first of October, from three-fourths of a ton to a ton and half of dry matter can be expected in the tops, depending upon the amount of available moisture and plant nutrients during this growing period. The tops together with the roots, therefore, add a considerable amount of organic matter to the soil.

Westerwolds ryegrass (*L. annum var. westerwoldium*) differs from ordinary domestic ryegrass in its strictly annual growth. It will produce about the same amount of growth as domestic ryegrass if planted by the first or middle of August. Being completely winterkilled, it will not produce any voluntary growth in the spring or interfere with subsequent crop cultivation.

Lolium subulatum, known as Wimmera ryegrass in Australia, is also an annual. It does not appear to develop as rapidly as the Westerwolds ryegrass, but the difference in growth is not great and it can be substituted for Westerwolds if the need arises.

The value of these ryegrasses as a green manure or winter cover crop depends to a large extent upon the nature of the soil and the weather conditions. One of these grasses, seeded at the rate of 30 to 35 pounds to the acre by the middle of August on land moderately high in fertility, with a moderate supply of rainfall, will produce a dense vegetative cover, and a considerable quantity of organic matter will be added to the soil.

Potato Variety Trials. (Ralph W. Donaldson, Walter S. Eisenmenger, and Karol J. Kucinski.) Based on yields, the ranking of potato varieties grown in plots at the college during the season of 1940 was Houma, Sequoia, Green Mountain, Sebago, Russet Rural, Earlaine No. 2, Chippewa, Irish Cobbler, Warba, Katahdin, and Mesaba. The average yield of all varieties mentioned was 50 percent more on plots sprayed twelve times than on plots sprayed only twice.

Downward Movement of Lime in Pasture Soils. (Arthur B. Beaumont.) In the spring of 1924 lime was applied as topdressing in two rates to certain plots used in a pasture experiment. In the fall of 1940, 16½ years later, samples of soil from these plots were tested for reaction. The results are as follows:

Depth at Which Sample Was Taken	Soil Reaction (pH) 16½ Years after Application of Limestone		
Inches	No Lime	3480 lb. per Acre	10360 lb. per Acre
0 - 4	4.5	5.6	6.9
4 - 8	4.7	5.1	6.6
8 - 12	4.7	5.3	6.0
12 - 16	5.1	5.6	5.6
16 - 20	5.3	5.6	6.1
20 - 24	5.5	5.8	5.9

The Effect of Fineness of Limestone on Soil Reaction. (Ralph W. Donaldson, Walter S. Eisenmenger, and Hrant M. Yegian.) How soon does liming become effective in sweetening soil and how do commercial lime products of varying fineness compare in this respect? These points are frequently raised by farmers and by lime manufacturers.

A preliminary study has been in progress eight months to observe what changes in pH are produced under a laboratory setup where commercial limes of differing fineness are applied to soil and results measured at frequent intervals by means of a Beckman glass electrode meter. Both limed and unlimed samples were kept in glass jars and maintained at optimum moisture conditions, with no plants being grown.

Five commercial grades of limestone, ranging from coarsely ground (50% through 60-mesh) to moderately finely pulverized (95% through 60-mesh), and one hydrated lime were thoroughly mixed with dry soil to furnish equivalent oxides and applied in three different rates—1½, 3, and 6 tons of (equivalent) limestone to the acre. These limes were compared on two Becket loams; one of initial pH 5.4 and the other a forest podzol of pH 3.6. Results obtained so far indicate:

1. With one soil (podzol), the sweetening effect of each lime was immediate and greatest at the first 10-day period of sampling. This condition remained fairly constant for about three months, after which differences between limed samples and the unlimed check decreased considerably.

With the other (less acid) soil, the initial change in pH induced by liming was also great; but after two months, in contrast with the other soil, differences between limed samples and the unlimed check tended in some cases to increase.

2. The finest lime (hydrated) produced the greatest change and the coarsest grade of limestone produced the least change in soil reaction. This distinction was measurable and consistent for these materials applied at all three rates and on both soils.

As would be expected, the three limestones of intermediate fineness produced changes of reaction between the two extremes. No consistent difference in effect was apparent between these intermediate grades except on one soil when they were applied at the 6-ton rate; then slight differences in soil reaction due to relative fineness of these limes became apparent.

3. Subsequent determinations made after an eight-month interval revealed varying rates of nitrate formation and accumulation, which increased the soil acidity. This was most pronounced where the finest limes had been applied, but occurred also to a marked extent in the check soil of initial pH 5.4 which at the end of the eight months had dropped to pH 4.3. If the nitrates had been removed from the soil solution by growing plants, the results might have presented a slightly truer picture of the effect of fineness of lime material in changing soil reaction.

Borax Trials on Alfalfa. (Ralph W. Donaldson, Walter S. Eisenmenger, and William G. Colby.) Borax, topdressed on 16 alfalfa stands in the state, and applied during November 1939 in strips at the rate of 25 pounds to the acre, controlled alfalfa yellowing on fields where it appeared after removal of the first crop of 1940. No yellowing was apparent in the early-season growth of the crop.

A yellowing of terminal leaflets, occasional bronzing, and more or less stunting developed on maturing plants of both the second and third growth of alfalfa located on approximately half the fields included in this investigation. These symptoms did not appear on the borax-treated strips, on which the plants stood out in contrast, showing better growth and normal color. These symptoms of boron deficiency did not develop during the early season when the rainfall was high but were associated apparently with the drier period of insufficient rainfall and later drought conditions prevailing until autumn frosts. Moreover, those fields which showed symptoms of boron deficiency were found to be predominantly those located on soils of the lighter texture (Merrimac). Little or no evidence of response to borax was observed this season on alfalfa located mostly on heavier soils, presumed to be of higher moisture content.

Symptoms of boron deficiency developed on plots of alfalfa which had received muriate of potash, 300 pounds to the acre, for three consecutive years. Since an application of borax corrected this trouble, it follows that muriate of potash in the amount applied did not correct a condition of boron deficiency in this case.

When borax (20, 30, 50, and 50 pounds to the acre) was applied in July at the time of seeding alfalfa and Ladino clover, temporary leaf injury and stunting of seedlings of both the legumes and weeds resulted at rates above 30 pounds to the acre. However, no injurious effect was observed the following season in character of stand or of growth from any rates of the borax applied. The soil was of limestone origin with pH around the neutral point.

COOPERATIVE TOBACCO INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture in Cooperation with the Massachusetts Agricultural Experiment Station.

C. V. Kightlinger, U. S. D. A., in Charge

Black Root-Rot. (C. V. Kightlinger.) Black root-rot is one of the most important diseases of tobacco in the Connecticut Valley. The project to develop new strains of Havana Seed which are more resistant to black root-rot and acceptable in type, yield and quality in the Connecticut Valley, is consequently being continued.

Selections from Havana No. 211 have been made to improve the strain. New strains have been produced by crossing strains of Havana Seed that are resistant to black root-rot with strains of common Havana Seed that are highly approved for type and quality. Selections from the progeny of these new strains and ther back-crosses are being tested.

Soil Treatments for Tobacco Seedbeds. (C. V. Kightlinger.) Damping-off diseases and weeds in tobacco seedbeds are important in tobacco growing in the Connecticut Valley. Treatments to control these troubles are consequently important.

Most of the large tobacco growers in the Connecticut Valley steam sterilize their seedbeds in the fall; a few steam treat their seedbeds in the spring. The practice of sterilizing tobacco seedbeds, however, is not so general in the Connecticut Valley as it should be. It is probable that more growers would sterilize their seedbeds if steaming equipment were not so expensive, or if other recommended methods did not cause inconvenience in application and delay in seeding. A method other than steam sterilization which would be effective, cheap, and convenient to use in controlling damping-off diseases and weeds in seedbeds, would mean much to the tobacco growing business in the Connecticut Valley.

Seedbeds which have been steam sterilized in the fall sometimes develop damping-off troubles because of subsequent contamination. Carelessness on the part of men working around the seedbeds may cause a large part of the contamination; but wind-blown earth, which is fairly common in the Connecticut Valley during the winter and spring of most years, is responsible for a considerable part of the contamination. Supplementary spring treatments for seedbeds steam sterilized in the fall, which would be effective against damping off, cheap, and convenient, would be a valuable aid.

Experiments were begun in the fall of 1940 to test the effectiveness of certain other treatments in comparison with steam sterilization, to control damping-off diseases and to kill weeds in tobacco seedbeds. The experiments include both fall and spring treatments. Preparation for the test was begun a year earlier by maintaining a seedbed to which earth infested with damping-off organisms obtained from seedbeds in various places in the Connecticut Valley, was applied during the spring and summer, to assure the presence of various types of damping-off organisms. Tobacco seedlings were grown from time to time in the seedbed throughout the spring and summer to increase the supply of damping-off organisms. Damping-off of tobacco seedlings was occurring in this seedbed when the soil was worked to prepare it for fall treatments of the experiment.

Overwintering of Common Tobacco Mosaic Virus in Soil Under Natural Conditions. (C. V. Kightlinger.) This project has been completed. The purpose was to determine whether common tobacco mosaic virus could overwinter in soil under natural conditions in the Connecticut Valley, and if so, then to determine how much mosaic would develop in succeeding tobacco crops with the overwintered virus as a source of inoculum. By way of summary of experimental results, it may be stated that the mosaic virus overwintered abundantly in the soil but that only a small percentage of the tobacco plants grown on the land developed mosaic.

DEPARTMENT OF ANIMAL HUSBANDRY

Victor A. Rice in charge

The Effect of Complex Mineral and Vitamin Mixtures on Milk Production, General Health, and Reproductive Efficiency in Dairy Cattle. (J. G. Archibald.) This project was completed during the past year. A confidential report was furnished to all interested parties, but release of the results in a general publication is not contemplated. No benefits from the feeding of two of the three complex mixtures investigated over a two-year period, were in evidence. Slight positive results were obtained from the third supplement fed. The following paragraphs are quoted from the confidential report on this particular supplement:

Although only one, or possibly two, of the differences between the groups of cows are of significance, nevertheless the general trend of the evidence slightly favors the group which received the supplement. These cows maintained their general condition slightly better than the controls did; they gave slightly more milk (1.4 lbs. daily); they required a significantly smaller number of services to get them with calf; and they had somewhat less trouble at calving time with retained afterbirth.

It is impossible, of course, to say definitely whether the supplement as a whole produced this desirable effect, or whether it was due to some one ingredient of what was a rather complex proprietary mixture, and, if the latter, what particular ingredient. It is our opinion, however, that the ingredient most likely to have been responsible for the slight benefits noticed was the cod liver oil the supplement contained. Results of a somewhat similar magnitude and trend were obtained a few years ago in an extensive trial of the merits of a cod liver oil concentrate added to the grain mixture for about half the milking herd of cows at the Massachusetts State College.

It seems probable that the price of the supplement (9 cents a pound at the time it was purchased in 1936) would prohibit its use by the average farmer. Fed at the rate of two percent of the grain mixture, it would add $3.60 to the cost of each ton of mixed grain. If, as we believe, the beneficial effect of the supplement is due to the cod liver oil it contains, sufficient cod liver oil concentrate to furnish 30,000 additional U. S. P. units of vitamin A per cow daily (an amount that along with the potential vitamin A in average quality roughage provides a reasonable margin over requirements) can be purchased for not more than $1.00 of additional cost per ton of mixed grain.

A Study of the Mineral Elements of Cow's Milk. (J. G. Archibald and C. H. Parsons.) For reasons outlined in last year's report, the work with iron in milk was repeated during the winter of 1939–40. In the earlier work done in 1938–39 only about as much supplemental iron was fed daily as calculation showed to be already present in the ration. In this more recent work from 3 to 4 times as much iron was added as occurred naturally in the ration; as before, the supplement was the readily soluble iron ammonium citrate.

Results were very variable, with no definite trend. Average amounts of iron were of the order of 0.3 mg. per kilo of milk or less, somewhat less than was found in the earlier work, due it is thought to refinements in method. As before, differences between individual cows in the same group or between samples from the same cow in different months were much greater than the average differences between the group receiving iron and the group that did not receive it. Irrespective of method of statistical handling of the results these average group differences were not significant. It is therefore concluded that the iron content of cows' milk cannot be consistently changed by feeding an iron supplement. Workers in other experiment stations have reached this same conclusion but with smaller numbers of cows and over shorter periods of time. The element manganese is being studied this year.

Investigation of the Merits of Legume and Grass Silage for Massachusetts Agriculture. (J. G. Archibald and C. H. Parsons.) Further work was done with phosphoric acid silage during the winter of 1939–40. In double reversal feeding trials with fourteen cows over a period of 3½ months, practically the same amount of milk was produced on this type of silage as on corn silage (39.30 lbs. daily per cow as contrasted with 39.35 lbs. daily per cow). However, the observations in last year's report regarding palatability and gains in live weight have been confirmed. Phosphoric acid silage was somewhat less palatable to cows than either corn silage or molasses silage, and gains in live weight were practically negligible when it was fed. Again this year phosphoric acid silage has produced milk of a finer flavor than that from cows on corn silage.

Our first extensive trial of the suitability of molasses grass silage for growing dairy heifers was made during the past winter in comparison with corn silage. In a double reversal trial 12 weeks in length, 18 heifers gained 7.3 percent in live weight when fed corn silage, and 6.3 percent when fed molasses grass silage. Average grade for condition, based on general appearance and handling was:

On corn	Good + + + +
On grass	Good +

The molasses silage was readily eaten by the heifers.

Results of this trial coupled with small weight gains noted when this type of silage is fed to milking cows lead us to the tentative conclusion that grass silage is better suited to milk production than to laying on of flesh.

A study of Urea as a Partial Substitute for Protein in the Ration of Dairy Cows. (J. G. Archibald.) This project was organized the first of the year in cooperation with the E. I. DuPont de Nemours Company of Wilmington, Delaware, and the Massachusetts State Department of Mental Health. Twenty-four cows in the herd of the Medfield State Hospital are included in the feeding trial, eight of them on a double reversal plan with periods eight weeks in length, and the other sixteen on a continuous feeding plan, eight to receive the regular herd ration for two complete lactations while the other eight receive a grain mixture in which urea has been substituted for the usual protein concentrates (cottonseed meal, soy bean oil meal, and gluten feed). The maximum amount of urea which it is planned to feed is 3 percent of the grain allowance (60 lbs. per ton). This amount has now been fed for over six months without untoward results. Cornstarch is being used to balance the energy content of the grain mixture which contains urea.

The first season's work with the eight cows on the double reversal experiment has been completed and summarized, and results from the first twenty-two weeks with the sixteen cows on the continuous feeding trial are also available. While final conclusions must await the outcome of another year's work, results to date indicate that, except for a slight superiority in the general condition of the cows receiving the regular ration, the two rations have had apparently similar effects.

The Effect of Feeding Irradiated Dry Yeast on Reproduction and General Health in Dairy Cows. (J. G. Archibald and A. E. Conklin.) This practice, established some years ago for the production of metabolized vitamin D milk, is being investigated for its possible beneficial effect on the cows themselves. The work is being done in cooperation with Standard Brands, Inc., of New York City and the Massachusetts State Department of Health. Sixty cows in the herd of the Gardner State Hospital have been divided into two groups, one of which receives the regular herd ration while the other receives in addition irradiated yeast (½ pound per ton of grain) for a period of two years. Careful records of milk production, reproductive function, and general herd health are being kept. The work has not yet been in progress long enough to yield any substantial amount of data or to warrant drawing any conclusions.

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

Nitrification in Soils Containing Plant Residues of High Lignin Content. (James E. Fuller.) This experiment is being carried on in cooperation with the Agronomy Department. In 1939 a number of plots were planted with crops having high lignin content. For comparison, some low-lignin crops were planted, and some plots were left fallow. In the fall the crops were plowed under. In 1940 tobacco was grown over the whole area. Soil samples were collected in the spring, in mid-season, and in fall. The ability of the soils of the samples to nitrify their own nitrogen and to nitrify dried blood was studied. The experiment is based on the theory that if it can be shown that certain crops plowed into the soil hamper the process of nitrification, it might follow that growth of plants (tobacco, for instance) would also be interfered with; and stunted, or even diseased crops, would result.

To date, no differences observed in the nitrifying capacities of the soils can be attributed to the crops plowed under. The experiment will be continued another year.

Bacteriological Study of Spices and Spice Oils. (James E. Fuller and Frederick J. Wishart.) Several standard brands of packaged spices were studied, including cinnamon, cloves, nutmeg, allspice, black pepper, red pepper, paprika, and mustard. The bacteria found were common air-borne varieties (*B. subtilis* group) that are of no particular sanitary significance. Intestinal bacteria (coliform group) were not present. Bacteria of intestinal types and of types capable of causing food poisoning (coliform bacteria, Salmonella strains, and staphylococci) inoculated into the several spices did not survive for more than a few weeks. Some oils of the spices were investigated and found to be sterile when they were purchased. Some were found to have the power to inhibit bacterial growth. More work will be done on this phase of the problem.

Effects of Temperature on the Differential Reactions of Coliform Bacteria. (James E. Fuller and Sonnia Levine.) The evaluation of the sanitary significance of certain members of the coliform group of bacteria in rural water supplies (springs and wells) offers some puzzling problems. The separation of definitely fecal strains from strains definitely of soil origin is relatively simple; but there are numbers of strains which give differential reactions between these two species, and the sanitary interpretation of the so-called intermediate strains presents the problems. Eijkman proposed incubating water-test cultures at 46° C., instead of at the usual 37° C., on the basis that the fecal strains would give positive tests for pollution (production of gas in lactose broth) at the higher temperature while other strains would not. In the present study the differential tests (Imvic reactions) of a number of intermediate strains were tried at several temperatures from 25° C. (room temperature) to 46° C. The evidence indicated that by this method certain of the intermediates could be placed in a group closely related to the fecal type (*Escherichia coli*). The indol test worked especially well in this respect.

Studies of Fecal Streptococci. (James E. Fuller and Robert S. Lubitz.) This study is a continuation of work previously reported (Fuller and Guiberson, Mass. Expt. Sta. Bul. 369, p. 20, 1940; France and Fuller, Amer. Jour. Pub. Health, 30 (9):1059-1062, 1940). In the bacteriological testing of swimming pool water, it is desirable to differentiate between fecal streptococci, and streptococci from the skin or from the nose and throat. The former would indicate pollution of the water from intestinal source, and the latter would indicate danger of skin or of respiratory infection to users of a pool.

In the study here reported an attempt was made to develop differential methods by the use of media of high pH value, or of high sodium-chloride content. Some information was obtained concerning the tolerance of fecal streptococci and of coliform bacteria to both high pH and high sodium-chloride concentrations in media. No successful differential procedure was developed.

Bacteriological Studies of Chocolate Syrups and Cocoa Powders Used in Chocolate Milk. (James E. Fuller and R. W. Swanson.) This study is being made in cooperation with W. S. Mueller of the Department of Dairy Industry. The work has been undertaken only recently, so only preliminary results can be given. The bacterial contents of the syrups and powders vary a great deal. There is little indication to date that the addition of either syrup or powder increases the bacterial counts of milk except for the addition of the bacteria present in the syrups or powders themselves. There is some indication that both chocolate and cocoa may have the capacity to hinder the growth of certain bacteria.

Studies of Methods for Determining the Sanitary Quality of Drinking Utensils. (Ralph L. France, W. E. Cassidy, and James E. Fuller.) Results obtained to date on this project are as follows: (1) The use of a wet swab on the glasses gives better results than a dry or a moist swab. (2) As a suspending medium and a diluting fluid phosphate water and saline were equally satisfactory. (3) A medium containing sodium chloride, yeast extract, neopeptone, and dextrose recovered more organisms than the standard plating agar. (4) All swabs should be iced immediately after collection if the elapsed time between sampling and laboratory testing is more than two hours.

The Streptococci Test as an Index of the Sanitary Quality of Drinking Utensils. (Ralph L. France.) A test for streptococci similar to that used in swimming pool sanitation might be used to determine the sanitary quality of drinking utensils. Results to date indicate that when a glass or cup has been improperly sanitized it is possible to obtain streptococci when the lip of the container is swabbed. In the case of a properly sanitized glass this is not possible. Further work of a practical nature will be carried on to add confirmation to these results.

Neisseria Catarrhalis as an Index of Pollution in Swimming Pool Water. (Ralph L. France.) The use of *N. catarrhalis,* an oral and nasal-passage organism, has been recommended as an index of pollution in swimming pool waters. A comparison of this method with the streptococci index and the coliform (Standard Method) index is being made. The results obtained to date suggest that the streptococci index is much more indicative of the actual sanitary conditions of a pool than is either of the other two methods. In fact, this writer has been unable, up to the date of this report, to isolate *N. catarrhalis* from swimming pool water by the method recommended.

Laboratory Service. (Ralph L. France.) Following is a list of the types and numbers of examinations made during the past year:

Milk (bacteria counts)	787
Ice cream (bacteria counts)	116
Water	150
Miscellaneous:	
Butter fats	2
Mastitis	2
Ropiness	1
Total	1,058

SUMMARY OF SERVICE BACTERIOLOGY—1928 TO 1940

Year (Sept. 1-Aug. 31)	Paid Examinations				No-charge Examinations				Total Examinations for the Year
	Milk	Water	Misc.	Totals	Milk	Water	Misc.	Totals	
1928-29 ..	432	*23 144	35	634	658	28	8	694	1,328
1929-30 ..	466	211	47	724	326	5	4	335	1,059
1930-31 ..	745	117	66	928	288	32	0	320	1,248
1931-32 ..	899	88	223	1,210	270	35	1	306	1,516
1932-33 ..	782	81	314	1,177	305	39	14	358	1,535
1933-34 ..	801	60	57	918	196	18	0	214	1,132
1934-35 ..	873	82	99	1,054	251	16	0	267	1,321
1935-36 ..	1,133	79	256	1,468	304	6	24	334	1,802
1936-37 ..	1,098	86	499	1,683	389	33	20	442	2,125
1937-38 ..	739	106	504	1,349	382	22	62	466	1,815
†1938-39 ..	595	118	410	1,123	418	5	25	448	1,571
†1939-40 ..	438	130	178	746	465	20	15	500	1,246
Totals ..	9,001	1,325	2,688	13,014	4,247	264	173	4,684	17,698
Grand Totals (Paid and No-charge)	13,248	1,589	2,861						17,698

*Chemical analyses.

†This sudden decline in the number of samples (mostly milk) can be traced directly to the installation of several municipal and private laboratories in this part of the state.

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Diseases of Trees in Massachusets. (M. A. McKenzie and A. Vincent Osmun.)

The Dutch Elm Disease Problem. State-wide interest in the Dutch elm disease was intensified during 1940 as reports of affected trees in Columbia County, New York, and Litchfield County, Connecticut, established new stations for the causal fungus, *Ceratostomella ulmi* (Schwarz) Buisman, in areas immediately adjacent to the west and south of Massachusetts' boundaries, and the total number of trees found to be infected in the United States rose to 61,391. At the present time (December 2, 1940), no positive proof of the disease in the elms of Massachusetts has been established although hundreds of suspected trees have been checked in field and laboratory studies during the past year.

The work of the organized project of this Station in collecting and studying specimens from trees showing symptoms macroscopically indistinguishable from those of the Dutch elm disease has been supplemented by other public and private groups and individuals, including the Massachusetts Department of Agriculture, United States Department of Agriculture, The Massachusetts Forest and Park Association, town and city tree wardens, employees of other municipal and State departments, arboriculturists, and private citizens. Recently in cooperative investigations the Director of Plant Pest Control of the State Department of Agriculture has seen fit to invoke the provison of the Massachusetts statute for the destruction of trees infested with carrier insects of the causal fungus in two instances where elms were believed to be dangerously threatened by the disease. Connecticut, however, remains the only New England State in which the presence of the Dutch elm disease has been definitely established, although a recent report in the eastern part of that State carries the disease to a point within ten miles of the Rhode Island line; and the presence of the disease in areas of infestation in New York near the Vermont line further threatens the elms of New England States other than Massachusetts.

During the past five years close surveillance of the elms in Massachusetts has revealed certain facts relative to the Dutch elm disease problem in Massachusetts. From time to time, considerable confusion has been encountered resulting from popular misunderstandings, of which the following is only one example. The necessity for accuracy in describing the disease as a result of infection by a fungus is frequently overlooked, and leaf beetles (which contribute to tree weakening) and bark beetles (which are believed to be the principal carriers of the causal fungus) are sometimes confused with the actual specific fungus disease. In practical application, however, the association of the various factors may not be far amiss if it is borne in mind that none of the factors which favor the development or spread of the disease can initiate the disease independent of the fungus which causes it. In a concise report[1] on this problem it was pointed out that the disease control program in the State has consistently worked toward the elimination of conditions which would be favorable to the establishment and spread of the disease within Massachusetts. Particular emphasis should be given to the reported danger from the carrier beetle (*Scolytus multistriatus* Marsh.) population in southwestern Massachusetts, which is continuous with the beetle population of the adjoining New York area where beetle-infested trees infected with the causal fungus have been found. The existence of a distinct area of infestation of this same carrier beetle in eastern Massachusetts has set the stage for the spread of the disease there if the causal fungus is permitted to be introduced and established widespread in the area, but obviously the elms of western and southwestern Massachusetts stand in more immediate danger because of the proximity of both the causal fungus and the carrier beetle.

The existence of a more or less natural barrier relatively free from elms in the southwestern corner of the State, together with the aggressive eradication programs for areas where the disease has been found may explain the delay in the spread of the disease to Massachusetts. Outside of Massachusetts, in programs for the eradication of the disease, 61,269 elms known to be infected with the disease fungus have been removed, in addition to 5,567,334 weakened or undesirable elms which have been removed because, as breeding places for carrier beetles or in some other way, they constituted conditions favorable for the spread of the disease. In Massachusetts, to the extent that municipalities are able to prevent the accumulation of elm material favorable for beetle breeding, a real obstacle to the rampant spread of the disease will be established.

If the fullest measure of benefit from the defensive campaign waged vigorously against the Dutch elm disease in the areas where the disease occurs outside of Massachusetts is to be realized, therefore, only a course of continued vigilance in an offensive and, if necessary, also a defensive campaign against the disease is open to Massachusetts.

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[1] Osmus A. Vincent. The Dutch elm disease situation as it concerns Massachusetts. Published among "Transcriptions of Certain Papers presented at the Seventh Annual Five-Day Short Course for Tree Wardens and Foresters," M. S. C., March 30, 1940.

Other Tree Problems. Seventy-one fungus diseases of thirty-five species of trees or other woody plants, including twelve diseases of elm, were identified from more than 600 specimens and inquiries received during the year. *Cephalosporium* sp. was isolated from elms of 16 municipalities in which the wilt disease caused by this fungus was not previously known to occur, making a total number of 152 cities and towns in which the disease has been found in Massachusetts. The progress of the disease in individual mature trees was found to be far from uniform. In experiments also, trees subjected to controlled conditions were found to be affected in varying degrees following inoculation with the causal fungus. The latter observations suggest the significance of resistant individuals, while field observations suggest that additional factors involved in susceptibility include winter injury and drought.

Preliminary experiments on another wilt disease of elm, caused by *Verticillium* sp., showed more extensive injury to maples inoculated with the fungus, in pots under controlled conditions. The Verticillium wilt disease of elm is believed to be caused by the same fungus which causes the disease of maple known as Maple Wilt as well as other diseases resulting from infection of the water-conducting tissues in numerous additional plants. When elms and maples were inoculated with the fungus isolated from elm, the elms died back somewhat but never completely, while the maples were sometimes killed. The isolation of *Verticillium* sp. from trees of six municipalities in which the fungus had not been reported previously, increased to 77 the total number of cities and towns where the Verticillium wilt disease of elm is now known.

During the year, experiments and observations of a fungus, *Phomopsis Gardeniae,* as a cause of injury to gardenias were reported,[2] [3] including in one instance a review of previous publications on this fungus.

The sycamore disease, caused by *Ceratostomella* sp., reported in New Jersey and elsewhere has not been found in Massachusetts as yet although so far as is known, no organized search has been made here.

A disease of maple known as Bleeding Canker has aroused widespread interest throughout the State. The fungus, *Phytophthora cactorum,* has been described as the cause of this disease by F. L. Howard and N. Caroselli.[4] A fungus believed to be the same species has been isolated in laboratory studies made from collections of elm, maple, and beech in Massachusetts, but no specific experimental work has been undertaken by this Station. The problem is recognized as a serious one since remedial treatment of affected, highly prized specimen trees may be desirable. Meager experimental work and the paucity of published data have resulted in a demand that work be undertaken by public agencies on this problem. The whole subject of tree therapeutics as well as the highly speculative and much misunderstood practice of tree injection is involved in this problem, which demands more concentrated attention than can be profitably accorded to this research as a side line dominated by other major work. It is recognized, however, that the demand for investigation on this problem is legitimate even if it cannot be met under present conditions.

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[2] McKenzie, Malcolm A., Jones, Linus H. and Gilgut, Constantine J. *Phomopsis Gardeniae* in relation to gardenia culture. Plant Disease Reporter 24:3:58-62. February 15, 1940. (Contribution No. 363.)

[3] McKenzie, M. A., Jones, L. H. and Gilgut, C. J. Study practical gardenia canker control as disease increases (illus.). Flor. Rev. March 28, 1940. (Contribution No. 367.)

[4] Phytopathology 30:11. 1940.

At the request of the Massachusetts Tree Wardens' Association a report entitled, "Mortality in street tree planting"[5] was prepared; and a paper entitled, "The tree warden and the town forest" was presented at the Fifth Annual Conference on Current Governmental Problems, November 15–16, 1940.

Investigation of certain injury to trees and other plants revealed evidence that sulfur dioxide fumes from an electric refrigerator had caused sudden if temporary damage.[6] [7]

Weather conditions of the early part of the 1940 growing season were particularly favorable for the spread of leaf-infecting fungi, and considerable injury to foliage also resulted in early summer from the burning of tender growth following foliage development. The period of dry weather previous to the freezing of the ground in the autumn of 1939 caused extensive injury to broadleaved and coniferous evergreens as well as less extensive injury to deciduous trees in certain localities.

Current miscellaneous activities of the project included the preparation of parts of the program of the Five-Day Short Course for Tree Wardens and the preparation of newspaper press releases.

Damping-off and Growth of Seedlings and Cuttings of Woody Plants as Affected by Soil Treatments and Modification of Environment. (W. L. Doran.) Sandy soil is proving to be a good rooting medium for cuttings of some species and a paper[8] was recently published on results obtained with it. Softwood, July, cuttings of *Styrax japonica*, *Cornus Kousa,* and Cornelian cherry treated with indolebutyric acid (12.5 or 25 mg. per liter for 18 or 20 hours) rooted 10 to 50 percent in sand, 70 to 100 percent in sandy soil. Untreated July cuttings of Pfitzer juniper rooted 100 percent in sandy soil, 83 percent and more slowly in sand; but hardwood, December, cuttings of that variety, after treatment (100 mg./l., 20 hr.), rooted better in sand. November cuttings of Gardenia rooted practically equally well in sand sterilized with hot water and in unsterilized sandy soil or sand–peat. Late fall cuttings of *Taxus media* and its variety *Hicksii,* treated with indolebutyric acid, rooted better in sand-peat than in sandy soil or sand, but untreated cuttings of *T. media* rooted 72 percent in sandy soil, 28 percent in sand. Similar cuttings of *Chamaecyparis obtusa* var. *filicoides,* untreated, rooted 57 percent in sandy soil, 28 percent in sand. November cuttings of *Picea glauca* var. *conica,* treated or not, rooted better in a mixture of sand, peat, and loam (3:1:1) than in either sandy soil or sand; best rooting, more than 90 percent, being of cuttings, treated with indolebutyric acid 50 mg./l., 18 hr.

Rooting of cuttings of white pine from mature trees has been considered difficult, but certain trees with unusually good characteristics from the viewpoint of the forester having recently been found here, their propagation vegetatively was attempted. There was little or no success with cuttings, treated or not, which were taken in spring and summer; but cuttings taken in late winter from the lower, not the upper, branches of a tree about thirty years old rooted 70 percent in sand-peat in three months after treatment for 5 hours with indolebutyric acid 200 mg. per liter. Similar cuttings failed to root without treatment, and treatment with more dilute solutions of indolebutyric acid for 20 hours was too long. Some of the results of this work were published recently.[9]

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[5] McKenzie, Malcolm A. Published in "Proceedings of the Annual Meeting of the Mass. Tree Wardens' Assn.," February 7 and 8, 1940.

[6] McKenzie, Malcolm A., and Jones, Linus H. Injury to trees from sulfur dioxide fumes of electric refrigerators. Science 91:2358:239-240. March 8, 1940. (Contribution No. 358.)

[7] Sulfur dioxide gas damages foliage. Science News Letter 37:2:184. March 23, 1940.

[8] Doran, William L. Soil as rooting medium for cuttings. Amer. Nurseryman 72:5:7-8. 1940. (Contribution No. 374.)

Solutions of root-inducing substances are more effective with cuttings of some species if used at higher than room temperatures. December cuttings of *Taxus media,* in sand, rooted 70 percent without treatment, 80 percent after treatment with indolebutyric acid (50 mg./l., 19 hr.) at an approximately constant temperature of 65° F., 100 percent (and more rapidly and with better roots) after similar treatment at an initial temperature of 86° F. for 3 hours followed by treatment with the same solution at 65° F. for 16 hours. November cuttings of *Picea pungens* var. *globosa* had their rooting improved by indolebutyric acid (25 mg./l.) applied at an initial temperature of 86° F., falling to 65° F.; but there was no improvement when it was applied at a constant temperature of 65° F.

Rooting of cuttings of several species, taken in late fall or early winter, was more improved by treatment for 16 to 24 hours with indolebutyric acid (50 or 100 mg./l.) in a sugar solution (2.5 percent) than by similar treatment with indolebutyric acid in water. Cuttings of Pfitzer juniper rooted 44 percent after treatment with indolebutyric acid in water, 100 percent after treatment with that acid in a sugar solution. Cuttings of a species of Cytisus rooted 40 percent in 16 weeks after treatment with indolebutyric acid in water, 60 percent in 7 weeks after treatment with that acid in a sugar solution. Cuttings of *Chamaecyparis obtusa* varieties *compacta* and *magnifica* responded similarly. Cuttings of *Taxus media* and *T. media* var. *Hicksii* rooted equally well, 100 percent, with either treatment, but the best roots were on cuttings treated with indolebutyric acid in a sugar solution. Cuttings of a variety of arbor-vitae and two varieties of Norway spruce did not respond to sugar, but cuttings of *Picea glauca* var. *conica* rooted 40 percent without treatment, 55 percent after treatment with indolebutyric acid in water, and 78 percent after treatment with indolebutyric acid in a sugar solution. Cuttings of Sawara cypress rooted in larger percentages after treatment with honey in solution, but there was no response on the part of cuttings of three other species.

Rooting of summer cuttings of Hinoki cypress and Pfitzer juniper was more improved by indolebutyric than by indoleacetic acid. Rooting of early July cuttings of a lilac was more improved by naphthaleneacetic acid (100 mg./l., 5 hr., gave best results) than by indolebutyric acid.

July cuttings of *Stewartia koreana* rooted less well if made of tips of shoots than if made to include all of the current year's growth. Best rooting, 100 percent, and much better than the untreated, was of cuttings treated with indolebutyric acid 50 mg./l., 20 hr.

Optimum concentrations of indolebutyric acid and lengths of time of treatment for cuttings of some other species were 25 mg./l., 20 hr., for Cornelian cherry (in July); 100 mg./l., 20 hr., for *Rhododendron minus* (in November); 50 mg./l., 20 hr., for *Picea glauca* var. *conica* (in November).

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[9] Doran, William L., Holdsworth, Robert P., and Rhodes, Arnold D. Propagation of white pine by cuttings. Jour. Forestry 38:817. 1940. (Contribution No. 372.)

Rooting of September cuttings of *Daphne Cneorum* was improved by treatment with 50 mg./l., 5 hr., or 12.5 or 25 mg./l., 20 hr. November cuttings of Gardenia rooted so well untreated that the only benefit of treatment (indolebutyric acid 25 mg./l., 24 hr., gave best results) was to hasten rooting a little. November cuttings of *Berberis candidula* rooted more than 80 percent without treatment, no better with treatment. December cuttings of Pfitzer juniper rooted 50 percent without treatment, 100 percent after treatment with indolebutyric acid 50 mg./l., 20 hr.

Study of Diseases of Ornamental Herbaceous Plants Caused by Soil-Infesting Organisms, with Particular Attention to Control Measures. (W. L. Doran.) Until better and cheaper soil disinfestants are found, it is important that more be learned about how best to use the old ones. Since damping-off is important and also convenient to work with, its control was here used as a measure of effectiveness, for what is learned in this way can be useful in efforts to control other and similar diseases caused by soil-infesting fungi.

In order to learn how the efficacy of certain soil disinfestants is affected by soil reaction, pH values of soil were adjusted with sulfur or with hydrated lime before soil treatment.

Formaldehyde was equally effective in soil with a pH value of 7.0 and in acid soils with pH values of 6.0 to 5.6.

Calcium cyanamide, 1000 pounds per acre, applied to soil two weeks before seeding, gave better control of damping-off and of a root-rot of sweet pea seedlings in soils with a pH value of 7.0 or higher than it did in a more acid soil with a pH value of 5.9. Sweet peas usually grow best, if they escape root-rot, in a soil which is not very acid and it was in such soil that calcium cyanamide was more effective.

Applications of acetic acid in the form of vinegar (about 200 cc. vinegar per square foot) which gave good control of damping-off in more acid soils at pH 5.7 to 6.0, gave poorer control in soils with pH values of 7.0 or higher. More vinegar is needed for good control in less acid soils and it was observed that a given quantity of vinegar can be used with greater safety in less acid soils than in those with a lower pH value. Growth of a few species was somewhat injured by vinegar applied to the more acid soils, but the growth of seedlings of all species used was unaffected or improved by vinegar applied to soil with a relatively high pH value. Growth of sweet peas was also improved by vinegar in the more acid soils for in such soils the control of root-rot was best. In soils with more lime, such as are usually used for sweet peas, vinegar would probably not, however, be the preferred soil disinfestant.

Aqua ammonia (containing 27 percent NH_3) prevented damping-off equally well in soils with pH values of 6.9 and 7.2 and in acid soils with pH values of 5.7 and 5.3. Aqua ammonia, 8, 16, or 24 cc. per square foot, gave good results; but 24 cc. per square foot applied 7 or 10 days before seeding injured some species, and 16 cc. but not 12 cc., interfered with the germination of beets sowed immediately after soil treatment.

Soil treatments with ammonium sulfate and ammonium phosphate were without fungicidal effect in acid soil (pH 5.4 to 5.9), but ammonium sulfate had some fungicidal effect in soil recently limed. Heavy applications of ammonium sulfate which were harmless to germination in acid soil were decidedly injurious in the limed soil. This is probably due to the effect of ammonia, the odor of which is sometimes strong when the salt is applied to limed soil.

With the object of determining the length of time that a soil-disinfesting effect persists, or how soon soils variously disinfested become badly reinfested, seeds were sowed at various intervals of time after treatment of soil in open flats in a greenhouse. Applied immediately before seeding, formaldehyde, calcium cyanamide, formic acid, salicylic acid, oxyquinoline sulfate, acetic acid, and vinegar were about equally effective although they were not equally safe; calcium cyanamide, especially, being harmful.

Formaldehyde gave good protection against damping-off for one week, fair protection for two weeks, very slight protection for three weeks, and none whatever when seeds were sowed four weeks after soil treatment. There was partial control by the other chemicals when seeds were sowed as late as four weeks after soil treatment. When they were sowed six weeks after soil treatment, the only chemical which still showed any protective effect was calcium cyanamide.

Chemical Soil Surface Treatments in Hotbeds for Controlling Damping-off of Early Forcing Vegetables. (W. L. Doran, E. F. Guba, and C. J. Gilgut.) In a continuation of the work of determining the least quantity of formaldehyde which is or may be effective and the search for more convenient ways to apply it, soil was watered, immediately after seeding, not with water alone but with dilute solutions of formaldehyde. They were so applied that each square foot of soil surface received 0.2 to 3.0 cc. formaldehyde in 1 quart of water.

There was poor or no control by 0.2 cc., but beet, cress, cucumber, and lettuce, the seeds of which germinate relatively rapidly, were well protected by as little as 0.6 cc. and nearly as well by 0.4 cc. per square foot. A little more may be needed when more slowly germinating seeds are involved, for seedlings of eggplant damped-off with 0.6 cc. But damping-off of all these species was as well controlled by 1.0 cc. per square foot as by heavier applications.

Such an application, 1 cc., leaves a considerable margin of safety, for 2 cc. per square foot did not injure the growth of seedlings of any species and injury to growth caused by 3 cc., slight to begin with, was soon outgrown. There is, however, more formaldehyde in recently treated soil during the germination of seeds than during the subsequent growth of seedlings, and it was several times observed that germination may be injured by applications which do not affect growth. Germination of the other species was not injured by 3 cc., but germination of cress was somewhat retarded by 2 cc., not by 1.6 cc., per square foot. Crucifers are especially susceptible to injury by formaldehyde and, for them, about 1.5 cc. formaldehyde per square foot, applied as above, is probably the limit of safety.

Dusting of seeds of crucifers with zinc oxide or, in some cases, with Semesan resulted in better stands of seedlings than did the application of formaldehyde to soil after seeding. Both zinc oxide and Semesan dust, as seed treatments, gave better results with crucifers than did red copper oxide.

Formaldehyde 1.9 cc. (in 0.8 quart water) per square foot gave good control of damping-off of spinach, lettuce, pepper, cucumber, beet, and tomato, but about 2.5 cc. gave better control with celery and Swiss chard. That quantity of water per square foot is not too much if soil is not too wet to begin with; but it caused some packing and puddling of soil which was already too nearly saturated before treatment.

Carnation Blight Caused by Alternaria dianthi S. & H. (E. F. Guba, Waltham.) Seedling carnations obtained from last year's breeding work are now benched and growing in the greenhouse. As yet there is no indication that any of the seedlings are more resistant than the parents to either Alternaria blight or branch rot caused by *Fusarium dianthi* Prill. & Delacr.

Control of Greenhouse Vegetable Diseases. (E. F. Guba and C. J. Gilgut, Waltham.) Observations on resistance of the Bay State tomato to the tomato leaf-mold disease caused by *Cladosporium fulvum* Cke. were made on crops grown under commercial conditions, in a number of greenhouses. Under such conditions, this tomato showed 25 percent of the plants to be susceptible to leaf mold while the remainder are highly resistant. The Bay State tomato is highly pleasing to growers who in the past have frequently experienced complete loss of their fall–winter crop due to this disease. The yield has been found satisfactory. The one criticism of growers is that the fruit does not ripen fast enough.

The Bay State tomato is not a substitute for good greenhouse management. In two establishments it was found that nearly all of the plants had some mold on them. It was learned that the impression was prevalent among growers that the plants could be more or less neglected and still remain free of mold. If managed as carefully as the highly susceptible varieties of greenhouse tomato, the Bay State variety, grown as a fall–winter crop, is highly resistant to the leaf-mold disease and gives far more satisfactory results.

Factors Affecting Yield of Onions and Their Shrinkage in Storage. (C. J. Gilgut and W. G. Colby. Cooperative with Agronomy.) Twenty-six lots of onion sets were grown on typical Connecticut Valley onion soil and compared for yield and shrinkage in storage. All lots were obtained in the Valley, except six small lots for experimental trial which were shipped direct from a mid-west producing area.

There was less difference in performance of locally grown Japanese seed sets and those shipped in than was the case last year. Locally grown Japanese sets produced slightly higher yields than those shipped in, but there was no significant difference in the yield of globe type seed sets from different sources.

After 90 days in storage, shrinkage resulting from disease averaged 17.8 percent for locally grown Japanese sets and 28.6 percent for three lots of shipped in Japanese sets. The average shrinkage of globe type sets was 24.5 percent for those grown locally and 25.7 percent for those shipped in. However, the lots of globe type sets obtained for experimental trial averaged 49.3 percent shrinkage. The large shrinkage loss in this case can probably be accounted for by the fact that the sets were shipped in airtight paper bags—the seed sets heated in transit and mold had developed on the basal plates. The development of mold did not affect the growth of these sets in the field. The average yield was highest of any globe sets tested.

In accordance with last year's results, it was found that in the early part of the storage period bacterial soft rot predominated, while later Fusarium bottom rot was more prevalent.

In harvesting experiments onions pulled, clipped, and stored the same day showed a shrinkage of 14.1 percent when stored in 50 pound crates, and 22.7 percent when stored in 50 pound bags.

In rotation experiments the shrinkage after 90 days in storage of onions grown after one year hay sod was 13.5 percent; of onions after a ryegrass cover crop, 22.4 percent; and of onions directly after onions, 17.3 percent. These are the first year's results on land which has produced onions continuously for more than 40 years.

Miscellaneous Tests and Experiments. (E. F. Guba and C. J. Gilgut, Waltham.)

1. *Apple Scab Control.* Wettable sulfurs used on an equivalent sulfur basis were compared for scab control, fruit russet, and leaf injury. All applications, except the pink and third cover sprays, contained 3 pounds of lead arsenate to 100 gallons of spray with or without 6 pounds of lime. Seven applications were made, beginning with the pre-pink on May 9 and ending on July 8. Delicious, McIntosh, and Greening varieties were used during the experiment. Fruit russet was found only on Delicious.

Kolofog, 6 pounds to 100 gallons, and micronized sulfur, 1.8 pounds to 100 gallons, used with 3 pounds of lead arsenate and with or without 6 pounds of lime, gave good control of scab on all three varieties of apples sprayed. Fruit russet produced by the Kolofog–lead arsenate spray was reduced from 17.9 percent to 9.6 percent when lime was added. The russet caused by the micronized sulfur–lead arsenate mixture was reduced by lime from 10.9 percent to 8.7 percent.

Magnetic sulfur, 1.8 pounds to 100 gallons, lead arsenate 3 pounds, and 1 pound of a commercial preparation of zinc sulfate gave less control of scab on McIntosh and Greenings, and slightly better control than most sprays on Delicious. Fruit russet was increased by this mixture.

The best scab control on McIntosh was obtained by Kolofog–lead arsenate–lime and by liquid lime-sulfur 2 gallons to 100 gallons in the precover sprays, and in the cover sprays magnetic sulfur 8 pounds, lead arsenate 3 pounds, manganese sulfate 2 ounces, soybean flour ½ ounce and lime 6 pounds. However, the latter treatment caused 23 percent fruit russet, a considerable increase over that produced by the wettable sulfur sprays containing lead arsenate with or without lime.

Leaf injury, as evidenced by yellow leaves, leaf drop, and the amount of foliage remaining on the trees at the time the apples were picked, was consistently more severe on those trees sprayed with the Kolofog–lead arsenate mixture. The most severe injury was on Delicious, which lost about 25 percent of the leaves, while the McIntosh and Greening trees lost about 8 percent each.

2. *Copper Dusts for Vegetables.* Eighteen brands of commercial prepared copper dusts were tested on cucumbers and muskmelons in the field. The copper content of the dusts varied from 3.15 to 8.8 percent.

The cucumbers were destroyed by mosaic very early in the season, in spite of good control of aphids, and no yield records or observations on fungus disease control could be obtained.

The melons grew well throughout the season and downy mildew did not appear until late. There was no noticeable difference in appearance of the foliage of the plots which were dusted and those which received no treatment. There was, however, a considerable difference in yield. The best yields were obtained with Copper Hydro Dust C (copper 8.8 percent, calcium arsenate 20 percent); Rohm and Haas Dust No. 4 (copper 5.16

percent, rotenone 0.75 percent, flour 5 percent; balance clay or talc); Copper Hydro Dust E (copper 8.8 percent, rotenone 0.75 percent); Lab 789 (copper zeolite to make 5 percent copper, calcium arsenate 10 percent, flour 10 percent, balance talc).

Dormancy of Gardenia Plants. (L. H. Jones.) A group of the Belmont strain of gardenias suddenly became dormant in the early autumn. The dormancy was characterized by a dark, dull green color and a cessation of growth. Passing the hand quickly through the foliage gave a sound as if the leaves were of paper. Attempts to break dormancy by extremes of temperature, high and low (55° F. to 90° F.), of both air and soil failed.

Of these dormant plants, more than half were infected with *Phomopsis gardeniae,* causing gardenia canker. The plants were to be used in experiments concerned with an investigation of soil temperature and chlorosis. It is known that the larger-flowered varieties, to which belongs the Belmont strain, react more quickly to any treatment affecting growth. These larger-flowered varieties are also more susceptible to the canker disease. In one greenhouse, in a bed of 231 plants, 71 percent were affected with trunk cankers.

For research work, other than problems concerned with disease, it is advisable to use *Gardenia veitchii.*

During the early winter of 1939, bud-drop was not prevalent locally, probably because of an above-normal amount of sunshine in the late autumn, which favored continued growth.

Changes in Root Temperature Cause Plants to Wilt. (L. H. Jones and G. E. O'Brien. Cooperative with Chemistry.) The sudden lowering of root temperature or the rapid increase of air temperature causes plants to wilt. The wilting may be followed by the death of tissue in areas along the margin and between veins. These drought spots indicate that water has been lost from these areas more rapidly than it could be absorbed by the roots. Root media of soil, sand, or water were all equally inefficient in protecting the plant from this type of injury.

Soybean plants, even in solution culture, wilted and suffered drought injury when the solution was cooled from 70° F. to 50° F. by placing the culture in a water bath at 50° F. However, it was learned that the plants can be acclimated to this low temperature if the temperature is slowly reduced during the dark hours of the night.

Stimulating Photosynthetic Activity. (L. H. Jones and B. Eames.) Negative results were obtained from tests of a proprietary eosin-like material designed to increase growth by stimulating photosynthetic activity. The tests were made with begonia and geranium plants during the winter, when sunlight is at a minimum and when results would be most marked and most advantageous. Check plants and test plants received equal amounts of water and light. The chemical in solution form was applied weekly to the test plants which, at the end of the period, showed no increase in root development, size of plant, or number of blossoms, as compared with the check plants.

The Effect of Root Media on Root Structure. (L. H. Jones and B. Eames.) There is evidence accruing to indicate that artificial soil and substitutes for soils alter the root systems of plants. Roots developed in one extreme of media, as sand, will sustain the plant when put into the other extreme, i.e., water; but new growth must wait until a new set of roots is produced. Literature intimates that there is a difference in roots in different media, but there is no information in regard to just what the difference is. A study with the microscope may reveal certain differences of structure.

The Nature of an Oxidant in a Nutrient Solution. (L. H. Jones, C. A. Peters, and W. B. Shepardson. Cooperative with Chemistry.) When the solution of a soybean plant culture is covered by a mineral oil film, an oxidant is produced in the solution that can be quantitatively determined by the Micro-Winkler method for the determination of dissolved oxygen. The oxidant is not O_2; it is cumulative in the solution but not cumulative in the plant; it is produced by a living plant but not by a dead plant; the small amount of nitrites sometimes associated with it does not interfere with the quantitative determination.

If, in determining the oxidant by the Micro-Winkler method for oxygen, the sample is allowed to stand for a half hour after it is ready for titration, no returning end point is obtained. However, if the sample is titrated immediately, the end point is indefinite and continuing. This end point, if continued, will eventually come to the same figure as obtained after the half hour wait. The production of this oxidant by a plant is not understood and its composition is unknown. Some facts about its action under various conditions may aid in determining more exactly the nature and substance of this particular oxidant.

DEPARTMENT OF CHEMISTRY

W. S. Ritchie in Charge

Cooperative Analytical Service. (The Department.) Thirty-four samples of blueberry bushes raised in the greenhouse in sand cultures by the Pomology Department were sent to the laboratory to determine their response to various nutrient solutions. The yield of air-dry leaves was determined in all cases, and the percentages of nitrogen, crude ash, and iron in dry matter in 13 composites. The yield in several instances was so small that further investigation was not possible. Freezing-point determinations were made on ten of the nutrient solutions as a measure of concentrations.

The manganese, calcium, and phosphorus were determined in a poultry ration as well as in the calcite added to it. The manganese in the egg (shell and yolk) was also determined as part of the study to evaluate the role of this element in the life processes of the chicken. Details of this work will appear under the report of the Poultry Department.

Spray materials. Several samples of spray material were submitted for analysis, including two lots of nicotine, fish-oil soap cartridges used for the control of aphis, which tested 6.79 and 5.83 percent of nicotine respectively. The soap in both instances was fairly soluble and left but slight residue.

A sample of so-called Fruitone, which is applied as a spray to retard apple drop, was received from the Pomology Department. This was a fairly soft white powder used at the rate of 1 pound to 200 gallons, and consisted of about 54.50 percent of talc (spreader) and 39.50 percent of organic acids (as citric by titration), together with some hygroscopic moisture and a small percentage of declared naphthalene compounds.

Other service rendered included the analysis of cocoa for iron, the qualitative examination of material found to be limestone, and the determination of the strength of a commercial sample of formaldehyde.

Carotene and chlorophyll were determined in two standard samples and one local sample (spinach and alfalfa) by several methods as collaborative work on A. O. A. C. methods for these constituents in feedstuffs.

Testing Analytical Methods. (The Department.) In furtherance of the collaborative work on zinc in foodstuffs under the auspices of the A. O. A. C., samples of white dent corn (Johnson County Ensilage) and of spinach (Burpee's Victoria), together with granulated zinc for standardizing, were sent to analysts who had expressed a willingness to take part. Results by the Massachusetts method were promising, on the whole, but revealed some possible errors in technique that could be easily remedied. The suggestions for the coming year call for additional investigation to insure greater accuracy and easier operation as follows:

1. Complete solution of the zinc in hydrochloric acid.
2. Prevention or at least reduction of contamination by the glassware.
3. Use of dithizone in carbon tetrachloride when a suitable colorimeter and filters are available for a "mixed color" method.
4. Adoption of a specific color filter for the determination.

The Iron, Copper, Zinc, and Iodine Content of Fruits and Vegetables Used as Human Food. (E. B. Holland, C. P. Jones, and W. S. Ritchie.) The analyses of some 324 foodstuffs conducted during the past few years have now been completed. The analyses include proximate constituents and trace metals in fruits, vegetables, cereals, nuts, processed human and cattle feeds, and roughage.

Lignin and Its Relation to the Absorption of Minerals by Plants. (Emmett Bennett.) A thorough description of the objectives of this project has appeared in previous annual reports.

Last year it was noted that when corncob lignin was dispersed in sodium hydroxide and titrated electrometrically with a strong acid, data were obtained which, when plotted, produced a titration curve having two inflection points—one at about pH 4.5 and the other at about pH 8.0. A study was made of the conditions necessary to reproduce this curve. Such behavior is indicative of the activity of definite chemical groups. In some instances data may be obtained from titration curves which may be of assistance in determining the nature of the active groups. From the data obtained in this study "apparent dissociation" constants were calculated. These values were found to be comparable to the dissociation constants of substances containing phenolic hydroxyl and weak carboxyl groups. This relative agreement, however, is not conclusive evidence of the presence of phenolic hydroxyl and carboxyl groups in the material tested.

A study of the base exchange capacity of purified lignin indicated a low value. However, solution in alkali followed by precipitation and subsequent electrodialysis increased the exchange value many times. The enhanced value of the specially prepared lignin was reduced to the level of that of the original by drying at about 80°C. The enhancement in capacity is believed to be due chiefly to increased state of hydration made possible by previous treatment.

Precursors of Lignin. Data obtained from an investigation on Kentucky blue grass (*Poa pratensis*) and red clover (*Trifolium pratense*) showed no apparent relationship between pectic substances, hemicelluloses, and lignin. The lignin in red clover was associated with approximately an equal amount of pectic substances. On the other hand, Kentucky blue grass, containing an amount of lignin nearly equal to that of red clover, showed little more than a trace of pectic substances. The older plants contained about the same percentage of the pectic substances as the younger ones. The percentage of total hemicelluloses in Kentucky blue grass was about twice that in red clover.

It seems, therefore, that variations in the proportions of the three substances in the two species are probably due to differences in cell structure rather than to transformations; and that pectic substances are not found chiefly in the younger tissues.

A description of this work can be found in *Science* 91:95-96, 1940; and in *Plant Physiol.* 15: 327-334, 1940.

Effect of Storage and Processing on Carbohydrates of Some Varieties of Edible Onions. (Emmett Bennett.) A description of this project was given in the annual reports for 1938 and 1939. The results from investigations on the storage of the Ebenezer onion indicated the following:

1. Soluble carbohydrates constituted approximately 60 percent of the dry matter of the onion.
2. Reducing sugars accumulated to the greatest extent in the coldest storage.
3. Loss of total soluble carbohydrates was negligible in the onions which remained sound in storage.
4. The chief losses in storage were due to decay and sprouting.
5. Low temperatures retarded the losses.

Boiling onions in the usual way for consumption decreased the content of non-reducing sugars about 13 percent.

Details of this work have been summarized and submitted for publication in the *Proceedings of the American Society for Horticultural Science.*

Chemical Changes in the Cooking of Vegetables. (M. E. Freeman and W. S. Ritchie.) The cells of baked potatoes are separated to a greater extent in mealy tissue than in waxy tissue. Previously it was shown that this does not seem to be caused by the lack or weakness of the pectinous cementing material between the cells. New technique has given additional evidence of the cell separation in mealy tissue. When slices of freshly baked potatoes are dried, the mealy tissue becomes very porous. In the waxy tissue, however, the cells adhere so firmly that the material shrinks to a dense vitreous mass. The difference between mealy and waxy tissue is so apparent that the texture can be easily scored. There are several important advantages in this method of scoring texture: (1) the dried slices can be kept as a permanent record of any test; (2) the permanent standards can be selected and used for direct comparison with any test; (3) standards can be easily exchanged by any laboratories that wish to compare their results on the same scoring basis.

From the foregoing observations, it would seem that a quantitative measure of the pore surface or pore volume of the dried slices might serve as a quantitative measure of texture. Preliminary experiments on this point have met with some success.

Texture is also highly correlated with dry matter (starch) or moisture content. This relationship has been confirmed by additional analyses for these constituents. It has been found that the specific gravity of the potato closely parallels the average moisture content, but that different parts of a tuber may vary considerably in moisture, specific gravity, and texture. When the moisture content of raw potatoes was substantially and uniformly increased, the specific gravities and, in many cases, the texture scores were lower than in the controls. The results, however, did not conclusively demonstrate a causal relationship between moisture content and texture. Moisture content of potatoes was successfully lowered only at higher temperatures, and these moisture losses were not uniform. Tubers lost 40 percent of their total moisture while the interior flesh lost only 1 to 3 percent.

The moisture–texture relationship has been investigated by studying the water-binding capacity of potato tissue and starch. Since none of the usual methods for the determination of bound water have been entirely satisfactory for these materials, modifications and their application to various starches and potato samples have been studied.

Progressive Decomposition of Fish Muscle. (W. S. Ritchie and P. N. Simon.) Changes in the physico-chemical nature of the proteins should mark the first stages in the progressive decomposition of fish muscle. Attempts to detect such changes have been made by extracting or peptizing fresh haddock muscle with water and with sodium chloride solutions of different concentrations and at different temperatures.

Typical peptization curves were indicated by the total nitrogen extracted. The maximum amount was obtained with 10 percent sodium chloride at 0°C for a 24-hour period. The slope of the curve varied with the time and temperature of extraction. Significant differences in the coagulable and non-coagulable protein fractions were obtained at 0° and 25°C with certain salt concentrations; but there was no significant change in the values obtained at 0°C with storage up to eleven days. There was, however, an apparent but unexplained increase in the total nitrogen of haddock muscle with storage time.

Twelve pounds of haddock muscle were stored for twenty days at 10° to 12°C and decomposition products were extracted with solvents.

An ethyl alcohol extract yielded a dark-brown gummy residue which was soluble in water but insoluble in ether and acetone. The components of this residue could not be separated or crystallized by dehydration. Separation by electrodialysis resulted in decomposition of the components at the cathode. Treatment with HCl effected only a partial crystallization.

N-butyl alcohol yielded mixtures of decomposition products that were easily decomposed by such mild treatment as vacuum distillation. Picrate derivatives were prepared, however, with some measure of success. Of the sixteen picrate preparations some were very unstable on recrystallization; all decomposed when heated in melting-point tubes. Identification of the picrate derivatives is being attempted by ultimate analysis.

The Influence of Base Exchange Capacity and of Exchangeable Ions in Massachusetts Soils on the Availabilty of Potassium. (Dale H. Sieling.) Samples of representative soils of Massachusetts have been collected and are being prepared for laboratory investigation. The various horizons of sixteen soils have been included in this collection, and from these samples information should be gained which will lead to the selection of the soils most suitable for this investigation when the phase of work related to plant growth is started. Preliminary investigations of the various physical and chemical characteristics of these soils are being made at the present time.

The Relationship of Base Exchange Capacity, Exchangeable Hydrogen, and Soil Reaction to the Lime Requirement of Massachusetts Soils. (Dale H. Sieling.) Sixteen soils representing the most important soil types in Massachusetts have been collected for the laboratory investigation in this research. Arrangements have been made with several of the farmers involved to lay out liming tests on a small area of their farms after the laboratory information is adequate to give an indication of the amounts required for the various soil types.

The volume–weight determinations of these 16 soils as they occur in the field have been made and show that under field conditions the weight per acre–inch varies from 101.5 tons to 151.0 tons. These variations in volume weights should have a marked influence on the lime requirements of the different soils on the basis of laboratory tests made on weighed quantities of soils.

The Fixation of Arsenic in Soils and the Influence of Arsenic Compounds on the Liberation of Fixed Phosphorus in Soils. (Dale H. Sieling.) Soil samples have been collected from plots 4 and 8 of Block K in the Pomology Fertilizer Test Plots. These plots have received the residue from several years of spraying with lead arsenate. On plot 8, where there has been no application of phosphorus, a definite deficiency of phosphorus is noted. Samples were collected at various depths in the soil to find whether the arsenic had penetrated beyond the top few inches of the soil.

CONTROL SERVICE

Philip H. Smith in Charge[1]

With the retirement of Mr. H. D. Haskins in December 1939, Fertilizer Control was merged with the other Control Services. At the present time, the Fertilizer, Feed, and Seed Control Laws and the Dairy Law are all administered as one service. In additon, a large amount of work is done not only for other departments of the institution, but also for other State institutions and for citizens as well.

Fertilizer Inspection. Records for the year show that 121 firms have registered 492 brands of mixed fertilizers and fertilizing materials and 52 brands of agricultural lime and gypsum. The gross receipts from the registration of the fertilizer and lime products and from fertilizer tonnage fees were $14,491.28.

For inspection purposes 1,815 samples, representing 534 brands and 13,254 tons of materials, were drawn from stock found in the possession of 425 agents or owners located in 157 towns and cities of the State.

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[1] The Control Service Staff consists of: Philip H. Smith in charge; F. A. McLaughlin, Seed Analyst and Microscopist; J. W. Kuzmeski, H. R. DeRose, A. F. Spelman, L. V. Crowley, F. J. Farren, Chemists; Jessie L. Anderson, Seed Analyst; James T. Howard, Sampling Agent and Inspector; G. E. Taylor, Laboratory Assistant.

The following summary shows the character of these substances, as well as statistics with reference to their inspection:—

	Brands Registered	Brands Collected	Samples Drawn
Mixed fertilizers	317	328	1,029
Ground bone, tankage and fish	39	35	133
Nitrogen products, mineral and organic	47	40	214
Phosphoric acid products	26	25	121
Potash products	21	21	84
Dried pulverized natural manures	26	26	95
Nitrate of potash	7	6	18
Peat products	2	2	3
Wood and cotton hull ashes	5	5	9
Miscellaneous	2	2	8
Lime products	52	44	103
Totals	544	534	1,817

Feed Inspection. During the fiscal year 1,628 samples of feeding stuffs were officially collected and examined in the control laboratories. The gross receipts from the registration of feeding stuffs in 1940 were $25,300, derived from 1,265 brands at $20 each.

Dairy Law. During the year ending December 1, 1940, 7,838 pieces of Babcock glassware were tested; 93 certificates of proficiency were awarded; and 235 creameries, milk depots, and milk inspectors' laboratories were visited in order to check methods and to pass upon equipment in use. As a result of this inspection, three machines were condemned. These will be either replaced or put into condition to operate satisfactorily.

Miscellaneous Analytical Work. (Fertilizer and Feed Laboratory). In addition to the work required by the several regulatory activities under its administration, Control Service is interested in collaborative work with other departments of the Experiment Station and College; the examination of samples of feeds, fertilizers, and other agricultural products submitted by citizens of the State; the testing of feeds and fertilizer bought by State institutions; and investigational work on new methods of chemical analysis for the Association of Official Agricultural Chemists.

In order to indicate the wide scope of the work, the following statistical data are appended:—

Apple spray residue	7
Feeds, from farmers and dealers	63
Feeds, from State institutions	959
Feeds and forage crops, Experiment Station	348
Fertilizer mixtures	40
Ice Cream	113
Insecticides and fungicides	7
Limestone (AAA distribution)	26
Milk	351
Peat	11
Poultry feces (In connection with experiments)	76
Poultry grits	3
Poultry manures (Fertilizer)	3

Referee and check samples, fertilizer and feed	17
Tannin in cocoa	24
Specimens for mineral poison	5
Sewage deposits	4
Superphosphate (AAA administration)	19
Water	3
Miscellaneous	10

Seed Control. From December 1, 1939, to December 1, 1940, the Seed Laboratory received and worked 2900 samples of seed, of which 1055 were collected by the State Commissioner of Agriculture and 1845 were sent in by seedsmen, farmers, and various State institutions. In addition, 194 samples of flower seeds, for field tests only, were also received from the State Commissioner of Agriculture.

Classification of these samples, with the total number of laboratory tests involved, is shown in the following summary. It will be noted that 4100 tests were required for the 2900 samples; 870 for purity, and 3230 for germination.

Number of Samples		Number of Tests	
		Purity	Germination
721	Field Crops for Purity and Germination	721	721
5	Field Crops for Purity Only	5	......
181	Field Crops for Germination Only	......	181
103	Lawn and Other Types of Mixtures for Purity, Germinations involving 440 ingredients	103	440
41	Lawn Mixtures for Purity Only	41	......
13	Lawn Mixtures for Germination Only, Germinations involving 52 ingredients	......	52
1542	Vegetables for Germination Only	......	1542
43	Herbs for Germination Only	......	43
98	Flower Seeds for Germination Only	......	98
147	Tobacco Seeds for Germination Only	......	147
6	Tree Seeds for Germination Only	......	6
2900	Totals	870	3230

Field tests to determine trueness to type were conducted in cooperation with the Departments of Olericulture, Floriculture, and Agronomy, which tested 253 samples of vegetable seeds, 194 samples of flower seeds, and 123 samples of corn, respectively.

The Seed Laboratory cleaned 2 lots of onion seed and 100 lots of tobacco seed for Connecticut Valley farmers. The gross weight of the tobacco seed was 156.7 pounds and the net weight for the cleaned seed was 121.5 pounds.

Corn, oats, barley, and wheat, (187 samples), purchased by various State institutions, were examined for conformity to grade purchased; and 84 samples of ground cattle and poultry feed, collected by inspectors or sent in by dealers and farmers, were examined microscopically.

THE CRANBERRY STATION

East Wareham, Massachusetts

H. J. Franklin in Charge

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.)

Hill Fireworm (Tlascala finitella (Walker)). In the last annual report of the cranberry station,[1] some pupae of this species were mentioned as remaining on November 27, 1939. These pupae lived through the winter and spring and their moths emerged June 9 to 15. These moths were all somewhat larger than those that had come out in late August and early September, their wing expanse being about fifteen-sixteenths of an inch and their length to their wing tips about seven-sixteenths of an inch.

A severe infestation by this insect occurred this season on a bog at Onset, Mass., over an acre replanted in May 1940 being badly damaged.

Cranberry Weevil (Anthonomus musculus). The following treatments were tried on this pest:

1. Six pounds of tartar emetic and 24 pounds of brown sugar in 100 gallons of water, 400 gallons to an acre, applied on June 8, 1940, reduced the count in a week from 52 to 20 weevils to 50 sweeps of the net, and only a very light infestation of the new brood was found on the treated area on August 6.
2. Basic copper arsenate, a new product of the Sherwin-Williams Co., applied on August 6 at the rate of 6 pounds in 100 gallons of water, 400 gallons to an acre, killed 94 percent of the weevils of an infestation of 134 to 50 sweeps of the net.
3. A broadcast of 200 pounds to an acre of Go West weevil bait on June 6 reduced an infestation of 210 weevils to 50 sweeps of the net 68 percent in 8 days.
4. Barium fluosilicate, applied on August 6 at the rate of 6 pounds in 100 gallons of water, 400 gallons to an acre, killed 90 percent of the weevils of an infestation of 86 to 50 sweeps of the net.
5. Cryolite used as a spray, 6 pounds in 100 gallons of water, 400 gallons to an acre, or as a dust, 30 pounds to an acre, was very effective in many cases but only moderately so in others. This variation in results may have been due to different timing of the treatments relative to the main feeding periods of the weevils.

In the experience with this insect so far, the Bordeaux mixture–calcium arsenate–soap spray, basic copper arsenate spray, cryolite spray and dust, and very high grade (Kenia) pyrethrum dust have been the more effective insecticide treatments.

Cranberry Aphid (Myzus scammelli Mason). This species, lately described as new,[2] has been under the writer's observation for thirty years. It is found only on bogs which are not reflowed during the growing season. It is sometimes quite abundant and would be an important pest were it not well checked by its natural enemies, the larvae and adults of the following lady beetles, named in the order of their importance in this, being very effective[3]; *Coccinella transversoguttata* F., *Coccinella 9-notata* Herbst., *Hippodamia parenthesis* Say, *Coccinella* 11-*punctata* L.

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[1] Mass. Agr. Expt. Sta. Bul. 369:34. 1940.

[2] Mason, Preston W. A revision of the North American aphids of the genus Myzus. U. S. Dept. Agr. Misc. Pub. 371, pp. 2, 5, 18. 1940.

Cranberry Root Grub (*Amphicoma vulpina*). One of the cranberry growers made an interesting attempt to kill the grubs of this pest by flooding an infested bog on May 10 with a solution of sodium cyanide, 6 ounces to 100 gallons of water. The cyanide was added by a measured feed to the water of the flood at the flooding gate in the form of a strong stock solution. This poisoned flood remained on the bog 27 hours, and analyses made from time to time showed that the poison was disseminated over the bog in quite even strength and that its strength was well maintained. This treatment did not harm the cranberry vines noticeably, but it killed hardly 70 percent of the grubs, being very definitely less effective than the usual cyanide application with pumping rigs and hose. It was also, of course, much more costly.

On May 15, paradichlorobenzene was used to kill these grubs. It was applied with a fertilizer distributor, at the rate of 600, 800, and 1200 pounds to the acre on different plots, and then covered with nearly an inch of sand. It was necessary to use the chemical in crystals of the particle size of very coarse salt, for larger crystals did not feed through a distributor well and fine ones did not sift down through the cranberry vines so as to cover the bog floor beneath them evenly. The chemical slowly volatilizes into a non-inflammable gas five times as heavy as air and permeates the surface soil thoroughly. The gas acts slowly and takes several weeks to kill insects. In these experiments, the kill was finally practically complete with 1200 pounds to the acre, and 800 pounds killed half the grubs. Further experience with this treatment is needed, but it may be useful on bogs that drain into public water supplies or into waters with fish, where cyanide cannot be used safely. It is much costlier than the cyanide treatment, the price of paradichlorobenzene being about 12 cents a pound.

Paradichlorobenzene was also applied to a large plot on August 10, at the rate of 1200 pounds to an acre, and the resulting kill in this case, as determined on October 7, was very unsatisfactory.

Gypsy Moth (*Porthetria dispar*). Cryolite used as a spray, 6 pounds in 100 gallons of water, 400 gallons to an acre, and as a dust, 30 pounds to an acre, was effective in killing the caterpillars of the gypsy moth and of the false armyworm in somewhat later stages of growth than is lead arsenate, but it failed to check maturing gypsy moth caterpillars. Derris powder (4 percent rotenone), 15 pounds in 100 gallons of water with 2 pounds of soap, 400 gallons to an acre, killed maturing gypsy moth caterpillars fully as well as pyrethrum dusts and at considerably less cost. Basic copper arsenate, 6 pounds in 100 gallons of water, 250 gallons to an acre, was more effective in killing maturing gypsy moth caterpillars than any other strictly stomach poison ever tried in our cranberry investigations. Though it was somewhat less effective than pyrethrum and derris, it probably will often be useful against the largely grown caterpillars where the crop prospect is poor and the main object is to save the vines.

Grape Anomala (*Anomala errans*). Grubs of this species were found early in May throughout a bog of 17 acres in the Wenham section of Carver.

Black-headed Fireworm (*Rhopobota*). Basic copper arsenate, 6 pounds in 100 gallons of water, 250 gallons to an acre, failed entirely as a treatment

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[3] Named by Dr. Richard Dow, Curator of Insects of the Boston Society of Natural History.

for this pest. A spray of cryolite, 6 pounds in 100 gallons of water, 300 gallons to an acre, was very effective against the first brood but failed to curtail the second well. Dusting with cryolite proved to be unreliable for either brood.

Blunt-nosed Leafhopper (*Ophiola*). Cryolite, 6 pounds in 100 gallons of water, 400 gallons to an acre, failed entirely as a control for this pest.

Cranberry White Grub (*Phyllophaga*). Considerable cranberry infestations by this species are found only in bogs that are flooded during the winter and have not been reflowed in late May or June for several years. Apparently such late reflooding interferes with the egg-laying of the beetles enough to serve as a control. Individual grubs of this insect are three times as destructive as those of the cranberry root grub (*Amphicoma*), and they travel around in the soil much more. The cyanide and the flooding treatments used against the root grub are also effective against the white grub. This white grub is always present more or less in the soil of the uplands around the bogs and it attacks the roots of cultivated blueberry plants extensively.

Cranberry Fruit Worm (*Mineola vaccinii*). Cryolite, 5 pounds in 100 gallons of water, 400 gallons to an acre, was fully effective against the fruit worm. Dusting with a mixture of 60 pounds of talc and 40 pounds of cryolite, at the rate of 60 pounds to an acre, was also effective. Spraying for this insect, in spite of its greater cost, is fully as advisable as dusting, for dusting seems to do more mechanical injury to the crop after the berries have begun to grow than does spraying.

Colaspis Rootworm (*Colaspis brunnea* var. *costipennis*). The infestation of this species described in last year's report[4] was kept under observation. The description of the full-grown grubs on June 12 was as follows: Length, about a quarter of an inch. Head pale yellow, the antennae not nearly reaching the tips of the mandibles. Body nearly white, without markings; the back and sides scattered over with simple pale hairs noticeable under a lens. Abdomen not noticeably darkened by its contents; the venter covered with a brush of brown hairs, those at the sides in clusters and larger than those across the middle, the latter arranged in transverse lines; the tip with a considerable prominence, ridged vertically at the end, extending caudad on each side of the anal opening. All the tarsal claws single, simple, slender, and sharply pointed.

This grub is much like that of the cranberry rootworm (*Rhabdopterus*), but its head is somewhat narrower relative to the width of the body than the head of that species.

The grubs all pupated about June 14, the winter water having been removed from the infested area early. The description of the pupa follows: Length about three-sixteenths of an inch. Color waxy white. Rather long, light brown hairs scattered freely over the upper surface of the head, thorax, and abdomen, many of them borne on conical pustules. Under surface of the body without hairs. Tips of the sheaths of the middle and hind legs each with a noticeable spine. Tip of abdomen truncate, with a strong, brown, somewhat curved spine on each side extending caudad; somewhat in front of these spines, a smaller straight spine extending squarely laterad on each side, and in front of this another spine extending caudolaterad.

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[4] Mass. Agr. Expt. Sta. Bul. 369:33. 1940.

These pupae waggle the abdomen very freely when disturbed. They are very much like those of the cranberry rootworm (*Rhabdopterus*) in habits, size, appearance, and structure and in the distribution and character of all the hairs and spines described above.

All the *Colaspis* beetles emerged from the pupal condition between the twentieth and twenty-sixth of June.

For comparison with the description of the *Colaspis* grub given above, a description of the full-grown grub of the cranberry rootworm (*Rhabdopterus*) is given here: Length, a little over a quarter of an inch. Head light brown, the antennae not nearly reaching the tips of the mandibles. Body whitish without markings; the back and sides scattered over with simple brown hairs noticeable under a lens. Abdomen not noticeably darkened by its contents; the venter covered with a brush of brown hairs, those at the sides in clusters and larger than those across the middle, the latter arranged in transverse lines; the tip with a rounded light brown plate on each side of the anal opening. All the tarsal claws single, simple, slender, and sharply pointed.

Cryolite has come to stay as a cranberry insecticide. About 17,000 pounds of it were used on Massachusetts bogs during the season with generally satisfactory results. It takes four or five days to effect its kill, but it stops worm feeding on foliage very soon. It will be useful mainly against the fruit worm and as a substitute for lead arsenate where that has been used heretofore late in May. The weevil and the black-headed fireworm should soon cease to be troublesome where it is used fairly regularly against the gypsy moth and false armyworm. It doesn't seem to control spanworms as well as arsenate of lead.

Anhydro Hexitol–Cocoanut Oil Fatty Acid Esters. Aqueous dispersions of esters of anhydro hexitols and cocoanut oil fatty acids were tried against the cranberry spittle insect, the black-headed fireworm, and the blunt-nosed leafhopper. They failed to control any of these insects to any noticeable extent even when they were used in such strength that they completely destroyed the cranberry inflorescence.

Prevalence of Cranberry Pests. The relative general abundance of cranberry pests in Massachusetts in the 1940 season, as judged by general observations and by the opinions of cranberry growers, was as follows:

1. Gypsy moth in Plymouth County about as abundant as in 1939; quite destructive on the outer Cape, but less so than in 1939.
2. Blunt-nosed leafhopper about the same as in 1939.
3. Cranberry fruit worm greatly more abundant than in 1939, more destructive than for many years.
4. Black-headed fireworm about as usual.
5. Firebeetle (*Cryptocephalus*) very much less prevalent than in the last few seasons, only an occasional specimen being found anywhere.
6. Spanworms about the same as in 1939.
7. False armyworm much more generally prevalent than for many years. Blossom worm less abundant than usual. Other cutworms scarce
8. Cranberry girdler (*Crambus*) and cranberry weevil about as in 1939.
9. Cranberry spittle insect (*Clastoptera*) and tipworm (*Dasyneura*) noticeably more prevalent than in 1939.
10. Spotted fireworm (*Cacoecia*) scattered, but more abundant than usual.

Control of Cranberry Bog Weeds. (Chester E. Cross.)

Kerosene. The water-white kerosenes of five different refining companies were again tested for their vine-burning and weed-killing properties, with results similar to those of 1939: the Atlantic, Colonial and Gulf kerosenes were less harmful to cranberry vines than the others tried; Shell kerosene did more burning than the Shell product of last year. In order of increasing toxicity to vines they stood this year as follows: Atlantic, Gulf, Colonial, Shell, and Cities Service.

The various kerosenes were all about alike as killers of grasses, sedges, and rushes. Colonial and Shell were the most effective on loosestrife.

Studies were made of relative vine burn by kerosene under varying conditions of humidity, sky, time of day, and wind. High relative humidities correlated with severe vine injury; kerosene applied from 11 a. m. to 4 p. m. burned the vines, while applications made the same day from 5 to 9.30 p. m. did no harm. Air currents are intimately associated in this with the prevailing humidity; if the latter is high, winds make the vine burn excessive; if low, they hasten the evaporation of the oil, and the vines are not hurt. Kerosene always reduces the crop when applied after the blossom buds are fully developed.

Applied in small quantities to the bases of the plants, kerosene kills bayberry and sweet gale bushes as it does hoary alders. A heavy spray to the tops of these plants is equally effective.

Ferric Sulfate. The injury to cranberry vines, reported by many growers, can be avoided by spreading this chemical evenly and brushing it off from the vines after it is applied. The margin in tolerance between weeds and cranberry vines is rather narrow, and locally increased doses harm the vines. Moisture on the vines at the time of treatment caused much injury. Dry weather after the application makes the chemical more effective in killing weeds and reduces the hazard to the vines. Midday applications are best; late afternoon treatments, even when the vines seem dry, are apt to be harmful.

Ferric sulfate was rather widely used on bogs this year. It proved very effective on horsetail, small ferns, royal fern, hardhack, wool grass (*Scirpus cyperinus*), and spike rush or needle grass (*Eleocharis*) when a small handful was applied at the base of each plant. It works on the root system, killing it completely. The cranberry vines remain unhurt if it is used carefully. It is also effective used early in the season on asters, a broadcast of 15 to 20 pounds to the square rod being advocated. Needle grass can also probably be controlled in this way, though the permanence of its kill is uncertain.

Broadcasts of 20 pounds of ferric sulfate to the square rod killed 90 percent of the rice cut-grass ("sickle grass") even where the drainage was only five inches. As cut-grass infests poorly drained areas mostly, it is hard to control with kerosene. The bog soil should be kept as dry as possible during and after the treatment with ferric sulfate.

Ferric sulfate was effective when applied early in the growing season. Plots treated late in August and in September showed only moderate kills of the weeds, and the vines were hurt in many cases.

Ferrous Sulfate. A large number of plots treated in June and July proved that dry applications of ferrous sulfate watered at once with a sprinkling can are far more effective than those left to be dissolved by rain.

A dry broadcast, 30 pounds to the square rod, killed 98 percent of sensitive ferns; 40 pounds killed the same percentage of feather ferns and about 50 percent of long-leaved asters. Any heavier applications caused serious vine injury.

A solution of ferrous sulfate (1 lb. $FeSO_4$ to a gallon of water), tried on wild bean in June, was successful only when 3000 or more gallons were used to the acre. Some tip injury resulted then, but the treated plots were relatively weedless in August when vine recovery was complete. Wild bean had been cut down 90 percent, asters (long-leaved) 60 percent, manna grass (*Glyceria*) and reed canary grass 75 percent, haircap moss 90 percent, and feather and sensitive ferns 70 and 90 percent respectively. Treatments in May with this solution might be as effective in killing weeds, possibly without vine injury.

Iron sulfate solutions of varying concentration and quantity were applied to sensitive and feather ferns. It was concluded that dry applications for these weeds are more feasible.

Copper Sulfate. Solutions of this chemical caused some injury when applied the first week in August. The injury was to vine tips and was like the burning noticed on plots sprayed the last week in July 1939. Growers must not use this spray too early in years with a backward growing season.

Copper sulfate solutions are still the only effective treatment for "summer grass" (*Panicum verrucosum*). They burn the grass tops and prevent seeding. It is better to use 20 pounds in 100 gallons of water, at the rate of 400 gallons to the acre, than to use a stronger solution more lightly.

Solutions of copper sulfate were very effective in burning the tops of Joe-Pye weed (*Eupatorium purpureum*). This weed is common on only a few Cape Cod bogs but is a serious pest to many Wisconsin growers.

Copper sulfate, 20 pounds in 100 gallons of water, killed wild bean foliage nearly as well as sodium arsenate spray.

Paradichlorobenzene. This chemical, applied early in May with a fertilizer spreader, 600 pounds to an acre, and covered with sand, killed white violets very nicely and seems to be the most promising treatment for them so far found. It did not harm cranberry vines.

Ammonium Sulfamate and Sulfamic Acid. Ammonium sulfamate, scattered dry 1200 pounds to an acre, and sulfamic acid, scattered dry 1600 pounds to an acre, killed all weeds and cranberry vines, much as sodium arsenite and sodium chlorate do. They failed, however, to show any useful selective action.

Ocean Water. Tests on wild bean in July showed again that ocean water will kill down the weed tops for the rest of the growing season, but it was hard to apply enough to kill the bean without injuring cranberry vines a good deal. About half as many wild bean shoots came up this year on the areas treated with ocean water in July 1939, as were present when the treatments were made.

COOPERATIVE CRANBERRY INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Massachusetts Agricultural Experiment Station

H. F. Bergman, senior pathologist, Division of Fruit and Vegetable Crops and Diseases, in Charge

Oxygen Content of Winter Flooding Water in Relation to Injury to Cranberry Vines. (H. F. Bergman.) Continuing studies made previously, measurements of the oxygen content of the winter flooding water on several bogs were made at weekly intervals from January 22 to March 8, 1940. These bogs were flooded early in December and were under ice from the middle of December 1939 until about March 10, 1940. The oxygen content of the water on all bogs, from the time the first samples were taken until the ice melted, was less than 1 cc. per liter and in some instances was less than 0.5 cc. per liter.

There was no crop on two bogs on which the water was held until about the middle of May. On other bogs the water was withdrawn late in March or early in April and the crop varied from about normal to about one-half. From limited data available, it appears that vines which had produced a large crop are more susceptible to oxygen deficiency injury during the following winter flooding period than are vines which had produced only a small crop, probably because the former have less stored carbohydrates than the latter when placed under winter flood. Vines with an ample carbohydrate reserve are able to withstand an oxygen deficiency in the winter flooding water for a longer time than those with a small supply of stored carbohydrates. One of the bogs on which the oxygen content of the winter flooding water was determined showed no oxygen deficiency injury. This bog had a very light crop in 1939. Two other bogs which had moderately good crops (50-60 barrels per acre) in 1939 showed some oxygen deficiency injury. The injury was greater in more deeply flooded areas on these bogs, which were probably also areas of greater or more prolonged deficiency. The injury was manifest in the retardation in the development of flowering uprights and of the flowers themselves and in reduced fruit production, but there was very little leaf drop.

The fourth (State) bog showed the most severe oxygen deficiency injury on an area which had produced a relatively heavy crop (75-80 barrels per acre) in 1939. The injury caused a decided retardation in the development of new uprights and of the flowers and a marked decrease in yield, as well as much leaf drop in areas in which injury was most severe.

The reduction in yield was due mainly to the failure of flowers to set fruit, but very dry weather during the late summer also contributed by reducing the size of the berries. The number of flowers produced was normal with an average of four to five per upright in each of the main three varieties on the bog, Early Black, Howes, and McFarlin. The percentage of flowers setting fruit was as follows: Early Black, Section 5, 12.8; Early Black, Section 14, 15.5; Howes, Section 13, 10.2; McFarlin, Section 13, 12.1. A normal set in these varieties would average 30 to 35 percent.

Studies are being continued on the relation between the amount of stored carbohydrates during late fall and early winter and the probability of injury to vines from oxygen deficiency during the winter flooding period, and also on the relation of oxygen deficiency during the winter flooding period to the setting of fruit during the following summer.

Spraying Experiments for the Control of Rosebloom. (H. F. Bergman.) The following spray mixtures were applied June 20, 1940, on duplicate plots at the rate of 250 gallons per acre: bordeaux 10-4-100 and 8-8-100 each with 2 pounds of rosin–fish oil soap; basic copper arsenate 5-100 and 6-100; and yellow cuprocide 1½-100 and 2-100.

Bordeaux 10-4-100 and basic copper arsenate 5-100 and 6-100 gave complete control. Six days after the plots had been sprayed only a few living diseased shoots were found on plots sprayed with any one of these mixtures. Bordeaux 8-8-100 was considerably less effective than the 10-4-100 or than the basic copper arsenates. Yellow cuprocide 1½-100 and 2-100 were still less effective than bordeaux 8-8-100 and gave probably not more than 50 percent control.

Spraying Experiments for Cranberry Fruit Rot Control. (H. F. Bergman.) Spray tests were run on three bogs. The plots, the number of applications, and the time and rate of application were the same as in 1939 (See Bulletin 369, p. 40). The results are given in the table.

Table 1. The Effect of Some Fungicides on the Control of Rots on Four Different Cranberry Bogs in Massachusetts in 1940

Bog and Treatment	Number of Plots	Average Percentage of Rot		
		Oct. 1	Nov. 1	Dec. 1
State Bog S 8				
Bordeaux 10-4-100	3	0.4	2.5	6.2
Cuprocide-bentonite 3-4-100	2	0.2	2.0	5.4
Copper arsenate (basic) 4½-100	3	0.3	2.4	8.1
None (check)	5	0.5	3.3	10.3
State Bog S 14				
Bordeaux 10-4-100	3	0.3	2.1	7.5
Yellow cuprocide 1-100	3	0.3	2.9	9.4
None (check)	4	0.5	4.6	11.5
Bog No. 3				
Bordeaux 10-4-100	3	1.0	7.0	33.5
Cuprocide-bentonite 4-5-100	3	0.6	6.8	29.2
Yellow cuprocide 2-100	3	1.0	9.7	40.9
Copper arsenate (basic) 6-100	3	1.3	12.0	49.4
None (check)	5	1.4	12.0	40.0
Bog No. 9				
Bordeaux 10-4-100	3	3.1	4.7	8.9
Yellow cuprocide 1½-100	3	4.0	6.6	13.9
Copper arsenate (basic) 6-100	3	3.7	5.1	9.0
None (check)	5	6.1	10.9	27.0

The extent to which fruit rots were controlled on different bogs varied widely, apparently according to the density of vine growth. The best control was obtained on bog No. 9 on which the vines are least dense and the poorest on bog No. 3 which has the densest vines. There may be some other factor or factors involved, as somewhat better results have been obtained on bog No. 3 in other years; although this bog has been found, through experiments extending over a period of years, to be one on which the control of rot is very difficult. Judging from results obtained this year on bog No. 3, cuprocide–bentonite 4-5-100 appeared to be slightly superior to bordeaux 10-4-100 for rot control. Cuprocide-bentonite 3-4-100 on section 8 of the State Bog gave as good control of rots as did bordeaux 10-4-100. Yellow cuprocide 1-100 on section 14 of the State Bog had little effect in reducing rot. Basic copper arsenate 4½-100 also appears to be ineffective since on section 8 of the State Bog it reduced the rot, up to December 1, very little in comparison with untreated plots. Yellow cuprocide 1½-100, as shown by the results on Bog No. 9 where fruit rots were controlled most effectively by bordeaux 10-4-100 and by basic copper arsenate 6-100, seems definitely to be less effective than bordeaux for rot control. The results obtained with yellow cuprocide 2-100 and with basic copper arsenate 6-100 are not conclusive. Basic copper arsenate on bog No. 9 gave as good control of fruit rots as did bordeaux 10-4-100. On bog No. 3 neither yellow cuprocide 2-100 nor basic copper arsenate 6-100 reduced the amount of rot, up to December 1, as compared with that in berries from nonsprayed plots and basic copper arsenate appears even to have increased it.

Blueberry Disease Investigations. (H. F. Bergman.) Severe defoliation and dying-back of twigs and small branches, and sometimes also of main branches, was observed in two blueberry plantings in each of which from six to twelve bushes were affected. *Phomopsis* was isolated from material from both plantings. This fungus heretofore, except in the case of two bushes in the State Bog planting reported last year, has not been known to cause greater injury than the killing of the tips of twigs.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

The Cacao-Red or Tannin-Like Substances in Commercial Cocoa Powders. (W. S. Mueller cooperating with Control Service—J. W. Kuzmeski and A. F. Spelman.) Since it seemed possible that the cacao-red (tannin-like substances) in cocoa might be one cause of the observed decrease in growth rate of white rats when excessive amounts of cocoa were added to milk, the first step in the investigation was to analyze commercial cocoa powders for cacao-red. Authorities do not agree on the chemical composition of cacao-red and most of the methods of analysis are rather crude and somewhat unreliable. Ulrich's method was used in this study because it is the generally accepted method. By this method the amount of cacao-red in cocoa is reported as weight of the insoluble iron compound. Sixteen samples of commercial cocoa powders have been analyzed and values for the iron precipitate ranged from 2.62 to 15.59 percent, with an average of 10.83 percent. In general, unprocessed cocoa was found to have a higher cacao-red content than the processed cocoa.

It was thought that Ulrich's method could be improved by investigating the composition of the insoluble iron compound. Accordingly, the Control Service has analyzed the insoluble iron precipitate obtained from various samples of cocoa powder. The following analysis is typical for a number of samples:

	Percent
Ash	9.6
Fe in ash	38.8
PO_4 in ash	56.1
$FePO_4$ in ash	89.0
Fe_2O_3 in ash	8.2

Further analyses are necessary before definite conclusions can be drawn. However, the results to date indicate that values obtained for cacao red by Ulrich's method are somewhat high and that this error could be reduced by ashing the insoluble iron compound and subtracting the weight of ash from the weight of the iron precipitate.

Experiments are under way to determine whether or not there is a correlation between the amount of cacao-red in cocoa and the digestibility of the chocolate milk.

The Effect of Various Methods of Pasteurization on Chocolate Milk. (W. S. Mueller and L. D. Lipman.)) The methods of pasteurization which have been studied are the Electropure process at 162° F. and ordinary vat pasteurization at 143°F. for 30 minutes and at 160°F. for 15 minutes. Preliminary conclusions from this study are as follows:

1. The Electropure method of pasteurization gave smaller cream volumes than the vat process. When an unstabilized chocolate milk was used, sedimentation was greater in the Electropure-processed milk than in the vat-processed milk. On the other hand, when a stabilized chocolate milk was used, no marked sedimentation occurred in either process; however, the vat-pasteurized milk tended to show a very slight sediment of a few small particles, whereas the Electropure processed milk showed no sediment.
2. The method of pasteurization had no effect on the flavor except that the vat process at 160°F. for 15 minutes caused a slight cooked flavor in the finished product.
3. The Electropure process gave lower phosphatase results than the vat process except when the vat pasteurizing process was changed to 160°F. for 15 minutes. In such cases the vat process gave lower phosphatase results.
4. The vat method of pasteurization tended to cause a greater percentage reduction in bacteria count than the Electropure method. This difference was more noticeable when stabilized chocolate milks were processed, and especially when the vat process was changed to 160°F. for 15 minutes.
5. The Electropure process tended to produce a more viscous product, especially when the chocolate milk contained a stabilizer.

The Bacteriology of Chocolate Milk, Chocolate Syrup, and Cocoa Powders. (W. S. Mueller in cooperation with Department of Bacteriology.) For further information on this study, refer to report by Department of Bacteriology.

Improving the Flavor and Keeping Properties of Milk and Some of Its Products. (W. S. Mueller and M. J. Mack.) The antioxidative properties of the following sugars have been tested by adding them to susceptible milk: raw cane, raw cane treated with filter cell, etc., refined cane, raw beet, intermediate beet, pure granulated beet, beet molasses, refined blackstrap, corn sugar, and cane sugar with added extract of cereal flour. No significant differences were noted between the different kinds of sugars. However, considerable differences were noted between the refined and raw sugars. The refining process seems to destroy some of the antioxidative properties of the sugar.

Cocoa shell was found to contain an antioxidative substance nearly as potent as that obtained from the cocoa powder. Dried extracts of cocoa shell proved to be an effective antioxidant when added to milk. An attempt is being made to isolate the antioxidant from cocoa powder and cocoa shell.

It was found that puffed oat flour goes into solution more readily and has slightly better stabilizing properties than ordinary oat flour. The antioxidative properties of puffed oat flour were equal to those found in ordinary oat flour when these substances were added to susceptible milk. Puffed oat flour, however, imparted a stronger flour taste to both ice cream and milk than ordinary oat flour.

The Effect of Various Antioxidants on the Behavior of Gelatin or Other Stabilizers in Ice Cream. (W. S. Mueller.) Today some ice cream manufacturers are adding antioxidants to ice cream mix in order to improve the flavor of their product. This practice has brought up a new problem, for some antioxidants also possess stabilizing properties and may cause overstabilization of the ice cream unless the amount of stabilizer ordinarily used is decreased. Several antioxidants were found to affect the action of gelatin in ice cream. Some ice cream manufacturers want a product which combines the antioxidant with the stabilizer. This brings up another problem for the amount of some antioxidants which is necessary to protect the flavor would raise the stabilizer content in ice cream above maximum amounts set by some states. Oat flour used with gelatin is an example. Oat flour has been found not to interfere with the efficiency of gelatin in ice cream. Studies are being continued to find an antioxidant that is potent enough so that only a small quantity would be used and that would also combine with the gelatin.

Cooperative Study with the American Dairy Science Association Committee on Methods for Determining the Curd Tension of Milk. (W. S. Mueller.) The major factors studied during the past year were: the stability of the coagulant (N.1 HCl + .45 percent U.S.P. 1:3000 dry pepsin) when stored away from light in a refrigerator; design and sharpness of knife; design of coagulating vessel; effect of covering the coagulating vessel during coagulation of the milk; speed of knife or vessel; and feasibility of specifying surface readings instead of continuous or secondary readings.

Results so far obtained indicate that the coagulant need not be made fresh daily, and if properly handled may retain its activity for one week. A knife of smaller total diameter but with the same lineal cutting edge is being compared with the knife furnished with the Submarine Signal and American Curd-O-Meter instruments. The former knife gives readings which are approximately 15 percent lower than those obtained by the use of the standard knife. Covering the coagulating vessel increased the surface or maximum curd tension reading but had little effect on the secondary or continuous reading. No significant differences were noted in deviations from the average curd tension when surface and continuous readings were compared.

The Use of Corn Syrup Solids in Ice Cream and Ices. (M. J. Mack and L. R. Glazier.) A new sweetener for use in frozen dairy products has recently been made available—dry corn syrup solids. This product results from the dehydration of corn syrup to a stable, white amorphous powder which looks like confectioners sugar. The approximate analysis of corn syrup solids is: dextrose 21 percent, maltose 33.2 percent, dextrines, 43.3 percent, and moisture 2.5 percent. Since this sweetener is less expensive than sucrose, the partial replacement of sucrose by corn syrup solids is desirable, provided the quality of the finished product is not lowered by the change.

Sugars have two principal functions in frozen dairy products: one to contribute sweetness, and the other to improve body and texture. Sucrose is sweeter than the corn sugars. However, certain combinations of sucrose and corn syrup solids improve the body and texture more than an equivalent weight of sucrose. The relative desirability of the ice creams made in this study was determined by consumer preference tests. The consumers did not know the identity of the samples they were judging.

The replacement of 20 percent of the sucrose of ice cream by corn syrup solids did not make a perceptible change in sweetness; but when the replacement was 25 percent, some consumers recognized a slight lowering of sweetness, although the majority did not. As the replacement of sucrose by corn syrup solids progressed above this amount, more and more of the judges noticed a loss in sweetness of ice cream. The use of corn syrup solids improved the body and texture of ice cream; this was noticed by at least 70 percent of the consumers. The final preference of the majority of the judges was for the ice creams in which 20 or 25 percent of the sucrose was replaced by corn syrup solids, rather than for those containing sucrose alone. A somewhat higher replacement of 33 1/3 percent of corn syrup solids for sucrose was preferred in ices and sherbets.

There are several other effects produced by corn syrup solids in ice cream. When this sweetener replaced 25 percent of the sucrose, the mix viscosity was increased about 10 percent and the titratable acidity was increased very slightly, but the stability of the proteins of the mix remained unchanged. The replacement had no adverse effect on the whipping ability of the ice cream mix.

The use of corn syrup solids, in combination with sucrose, improved noticeably the body and texture of ices and sherbets, as well as ice bars. The formation of a surface crust of crystallized sucrose, which is often troublesome with ices and sherbets, was prevented by the replacement of one-third of the sucrose ordinarily used in these products by corn syrup solids.

The Appearance of Melted Ice Cream. (M. J. Mack.) When ice cream is scored, using the score card approved by the American Dairy Science Association as a guide, the melting appearance of the product is considered. Ice cream should appear smooth and creamy when melted; undesirable defects listed on the score card are "curdy," "wheys off," and "does not melt."

The melting appearance of ice cream is a factor of importance, yet it has been given little attention in research. Defects in melting appearance have been attributed to a partial loss in stability of the proteins of ice cream, caused by acidity development, unusual proportions of the minerals present, or faulty homogenization. Marked defects in melting appearance are undoubtedly caused by factors which affect the stability of the proteins, but this explanation does not seem to be true when the defects are slight.

A number of factors, in addition to those already mentioned, have been found to affect the appearance of melting ice cream, such as the composition of the mix. High butter fat content, low sugar concentration, and an excessive amount of stabilizer may all contribute to the difficulty. The kind of stabilizer used is also important, since stabilizers vary in their effect on the melting characteristics of ice cream. Fast freezing and hardening are both necessary in order to secure a smooth melting appearance. Dipped ice cream has a more desirable melting appearance than packaged ice cream, which shows that the percentage of overrun is also involved.

Ice cream which has desirable melting characteristics can be secured by the use of good ingredients, properly proportioned. The homogenization temperature and pressure must be satisfactory for the composition of the ice cream, and rapid freezing and hardening are also essential.

A Study of the Efficiency and Practicability of the Paper Milk Bottle. (J. H. Frandsen and M. A. Widland.) As far as the study went, no off-flavors seemed to be due to the paper bottles.

A Comparison of the Electropure and Vat Methods of Pasteurization. (Leo D. Lipman, J. H. Frandsen, and H. G. Lindquist.) Split batches of raw milk were pasteurized in (a) the Electropure at 162° F. for 16 seconds and in (b) a spray vat at 143° for 30 minutes. Preliminary conclusions from this study are:

1. The reduction in the vitamin C content of milk was less rapid in Electropure-pasteurized milk than in raw or vat-pasteurized milks.
2. The Electropure method gave better (i.e. lower) phosphatase results than the vat method.
3. Pasteurization by both methods decreased the cream volume. While the Electropure method tended to give a greater cream volume than the vat method, the difference was so small that no definite conclusions can be drawn as to which of the two methods of pasteurization results in a lesser decrease in cream volume.
4. There was no significant difference in efficiency of bacterial reduction between the vat and Electropure methods of pasteurization.
5. Electropure-pasteurized milk became oxidized less rapidly, less frequently, and to a lesser degree than vat-pasteurized milk. A cooked flavor was found more often and was more pronounced in vat-pasteurized milk than in Electropure-pasteurized milk.

DEPARTMENT OF ECONOMICS

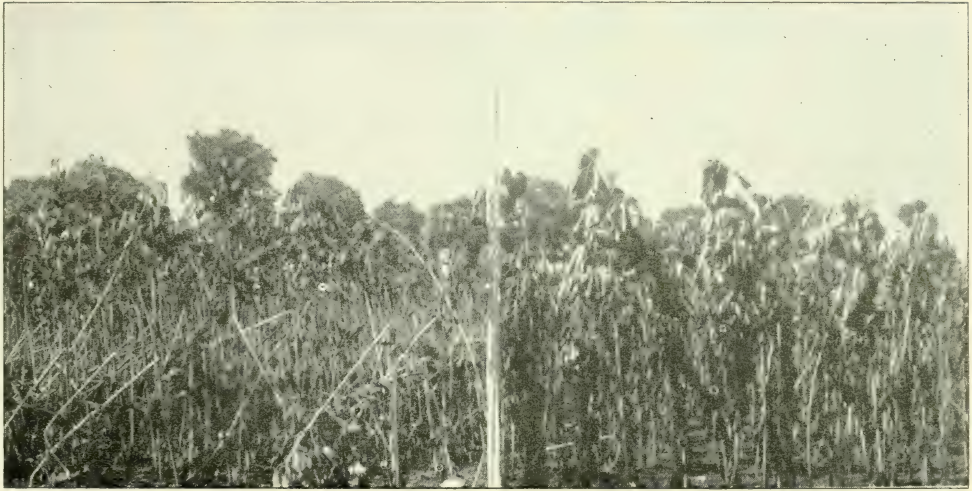
Alexander E. Cance in Charge

Land-Use Problems in Massachusetts in Relation to a Balanced Program of Land Utilization. (David Rozman.) The work on this project continued with the analysis of land-use factors in the light of economic and social conditions as they affect individual communities in rural areas. The program of land-use classification advanced to a point where detailed information is now available for over 300 rural towns of the Commonwealth. This includes the analysis of interrelationships between basic factors, as movement of population, tax rate, types of soil, land use and cover, road conditions, and other facilities and improvements in rural areas.

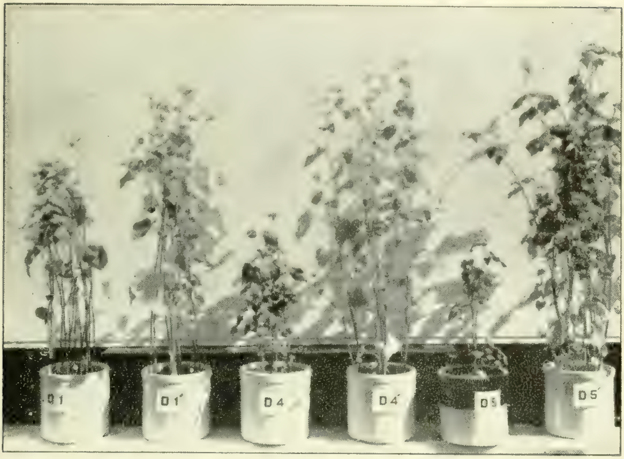
During the past year especial emphasis has been placed on the analysis of types of farming and the degree of diversification prevailing in various sections of the State. The study of these facts has been brought into prominence in connection with the accelerated defense program and the possibility of changes in the farming organization. These are expected to develop as a result of the shortage of farm labor and the changing level of prices for both farm products and the products purchased by the farm operators.

In Bristol County, where a complete analysis of the farm enterprises was carried out, a considerable amount of diversification is indicated. Out of a total number of 1,259 commercial and semi-commercial farms investigated, 647 or 51 percent had two or more farm enterprises; and of these, 205 farms, or 16 percent of the total number, had three or more different enterprises. The farms with only one enterprise numbered 612 or 49 percent of the total. The degree of diversification in commercial and semi-commercial farms compares favorably with that of farms operated on a self-sufficient or a part-time basis. The investigation and analysis carried out for the latter in the same county indicate only 33 percent of the total number of units having two or more enterprises.

It has been generally recognized that, whatever changes in farm organization are brought about as a result of the new influences, it is important to maintain a certain amount of self-sufficiency and diversification of enterprise to meet the conditions after the present acceleration of business activity is terminated.



Left: Two Sunflower Plants per Hill—Crop Almost Complete Failure.
Right: One Sunflower Plant per Hill—Strong Stalk with Large Seed Head.



The Effect of Increasing Dosages of Arsenic (As_2O_3) with a Constant Amount of Organic Matter on the Growth of Buckwheat.

D1—control; D1'—organic matter alone; D4—1500 p.p.m. of arsenic; D4'—1500 p.p.m. of arsenic with organic matter; D5—2000 p.p.m. of arsenic; D5'—2000 p.p.m. of arsenic with organic matter.

Hog Cranberry Used to Control Slope Erosion on Sandy Hills and Roadside Embankments on Cape Cod.

DEPARTMENT OF ENGINEERING

C. I. Gunness in Charge

Cranberry Storage Investigation. (C. I. Gunness, H. J. Franklin, and C. R. Fellers.) Cranberries from the 1940 crop were stored in a modified atmosphere. Berries were stored in air-tight steel cabinets, the covers being made tight by a water seal. Two rooms were operated: one at 35° and the other at 45°. Two cabinets were placed in each room. In one cabinet in each room an atmosphere of 5 percent carbon dioxide and 2 percent oxygen was maintained; and in the other, 10 percent of carbon dioxide and approximately 11 percent oxygen was maintained. The excess in carbon dioxide above 5 percent was removed by passing the air through a solution of sodium hydroxide. The deficiency in oxygen was supplied by ventilation. The 10 percent concentration of dioxide was maintained by ventilation.

The results of the experiment were not satisfactory. The means provided for removing the water given off by respiration were found to be inadequate. As a consequence the berries were wet when the cabinets were opened. Additional moisture was admitted to the cabinets by ventilation because the air for ventilation was drawn from an anteroom which was warmer than the storage rooms. The conditions would not exist in an actual storage as the refrigerating coils would tend to remove excess humidity through frosting of the coils.

Berries stored at 35° in 5 percent carbon dioxide and 2 percent oxygen showed practically the same loss as berries stored in air at the same temperature. The other lots of berries stored in a modified atmosphere showed considerably greater loss than those stored in air; but all lots were so wet that the excessive losses could be ascribed to the moisture rather than to the condition of the atmosphere.

Berries stored in the modified atmosphere showed less coloring than those stored in air, which would indicate less ripening in the modified atmosphere.

Apple Storage Investigation. (C. I. Gunness in cooperation with Department of Pomology.) A small room in the cold storage plant at the State College was lined with sheet iron and made gas tight for a trial in the storage of McIntosh apples in a modified atmosphere. A 5 percent concentration of carbon dioxide is maintained in this room, the excess being removed by a sodium hydroxide scrubber. Apples were placed in storage in September and no results are available until the storage is opened in the spring.

Frost Protection on Cranberry Bogs. (C. I. Gunness.) The wind machine as a means of protecting cranberry bogs against frost was given further trials, both in the spring and fall of 1940. Only a limited number of trials could be made each season and the results indicated that with a temperature inversion of 7°, protection was given over a circular area of 300-foot radius.

Poultry House Investigation. (C. I. Gunness and W. C. Sanctuary.) An investigation of the operation of electric brooders in colony houses was carried on during the past winter. Identical brooders were used in a conventional uninsulated brooder house, an insulated house, and an uninsulated house in which soil cable was placed on the floor for drying the litter. The litter in the first house was considerably wetter than that in the other two houses; and in the house provided with soil cable, the litter was drier than that in the insulated house. At the end of the trial the moisture in the litter in the uninsulated house was 48 percent, in the insulated house 37 percent, and in the house equipped with soil cable, 30 percent. Chick growth and feathering were practically identical in the three houses.

More electric current was used for the soil cable than was considered practical.

The work will be repeated during the coming season and an effort will be made to reduce the current consumption by rearrangement of the heating cable and reduction of the heating time.

DEPARTMENT OF ENTOMOLOGY

Charles P. Alexander in Charge

Investigation of Materials which Promise Value in Insect Control. (A. I. Bourne.)

Oil Sprays for Dormant Applications. (A. I. Bourne.) The close of the winter season was marked by much cold weather and snowfall considerably in excess of normal during March, while April was so unseasonably cold and wet that orchard and shade trees remained dormant throughout most of the month and seasonal development was very slow until May. Snowfall of 2.5 inches on April 12 and 13 and 4 inches on the 21st and 22d with accompanying low temperatures combined to hold the trees dormant but furnished very unfavorable conditions in the orchards for dormant applications of DN oils and similar sprays. It was difficult to operate spray equipment under such conditions, and the snow and low temperatures after applications of oils increased the danger of injury to sprayed trees.

The cooperative project with the Dow Chemical Company on a study of the value of DN sprays involved the use of different concentrations of dinitro-ortho-cyclo-hexylphenol (DNOCHP) powders dissolved in varying strengths of a commercial oil emulsion. Similar studies were made of dinitro-orthocresol (DNOC) and dinitro-phenol (DN-Phenol) compounds. These mixtures were tested in the college orchard for their effectiveness against overwintering eggs of European red mite and orchard plant lice. The infestation of European red mite in the experimental blocks was negligible, and the number of overwintering eggs of aphids was very much smaller than in 1939. The sprays were applied April 11 while the trees were in strictly dormant condition. Although there was a fall of 2.5 inches of snow the following day and an accompanying drop in temperature to 20° F., no injury resulted nor was any retardation in bud development noted. The DNOCHP–oil emulsion and DNOC–oil emulsion sprays gave practically perfect kill of aphid eggs. Unsprayed checks showed an average of 530 lice per 100 clusters on Baldwin and 890 per 100 clusters on McIntosh trees. On sprayed trees the number of lice was seldom greater than 1 per 100 clusters. The DN–Phenol combinations were noticeably less effective but gave good commercial control.

Solutions of ½, ¾, and 1 percent of DNOCHP in oils of 52, 87, and 108 sec. Saybolt viscosity, applied while the plants were in strictly dormant condition, caused no injury on various types of deciduous ornamentals or on white spruce, arborvitae, Irish juniper, and red pine. These oils at 4 percent strength applied to lilac caused no injury or retardation of development and gave excellent control of oystershell scale.

Tests of commercial DN sprays and the DNOCHP–oil emulsion on estates and in orchards in Plymouth County, in cooperation with Mr. R. E. Huntley, again showed control of rosy apple aphid in direct proportion to thoroughness of coverage. Troublesome infestations of oystershell scale and pear psylla were also controlled. Aphid attack was also checked on various species of Viburnum, a group which suffers severe curling, dwarfing, and distortion of foliage from even a light attack. The sprayed shrubs were very conspicuous in midsummer because of their flat, normal foliage in contrast to unsprayed checks in the vicinity.

One significant result of the season's work in that region was the condition of one orchard in which commercial DN sprays had practically eliminated rosy aphid in 1939. No spray, dormant or otherwise, was applied there in 1940. Inspection of the orchard in midsummer showed serious injury to the foliage and distorted terminal growth, and the fruit was largely "aphis apples." Subsequent examination at time of harvest showed the fruit of all varieties in this orchard to be worthless.

Summer Sprays for Apples. (A. I. Bourne in cooperation with Departments of Pomology and Botany.) Tests were made of certain variations of the standard spray program to determine the value of recent tendencies in spray practices and to contrast the liquid lime–sulfur with wettable sulfur for scab control. Tests of the present standard program were made to serve as the basis of comparison; the standard program with the addition of a mid-blossom application of wettable sulfur, without arsenicals; and the standard program without the use of lime in the cover sprays. Throughout the season these were contrasted with a program of wettable sulfur with the addition of lime in the cover sprays and a similar schedule with lime but no sulfur in the cover sprays. Lead arsenate was used at a dosage of 3 pounds per 100 gallons in the pink and 3d cover sprays; 4 pounds in the calyx and 1st and 2d cover sprays, and 2 pounds in the 4th cover spray. In the standard program lime-sulfur was used at the rate of 1½ gallons per 100. The wettable sulfur was applied at the rate of 7 pounds per 100 gallons. The pathologist found scab appearing on the check trees on May 22. It increased to the point where most of the leaves and much of the fruit were infested by late June. A light infection of scab appeared on McIntosh trees in the sprayed plots during the first half of June following the prolonged rainy period in late May. Only a slight amount of additional scab infection was observed in any of the sprayed plots during the remainder of the season.

In all plots where lime-sulfur was used, its typical injury was noted, especially following the pink and calyx applications. Foliage which appeared after those sprays, however, showed no such injury, nor was any injury noted on the foliage in the plots where only wettable sulfur was applied.

Examination of the fruit at harvest showed a considerable amount of russeting in the plots sprayed with lime-sulfur. This was particularly conspicuous in the plot where lime was omitted in the cover sprays. No russeting was noted in the plots which received wettable sulfur. The

McIntosh crop showed very little scab either in the lime-sulfur plots or where wettable sulfur was used in a complete season's program, although it was much more prevalent where sulfur was omitted and only lime was used in the cover sprays. Scab was found on 61 percent of the fruit from unsprayed trees. The record showed little or no significant difference between any of the programs followed, in the matter of relative control of insect pests.

Control of Striped Cucumber Beetle. (W. D. Whitcomb, Waltham.) Unfavorable weather conditions resulted in very poor growth of melons and cucumbers in the experimental planting at Waltham in 1940. Beetles did not appear in appreciable numbers until after July 1 and were less abundant than normally at all times. Of the 3029 beetles recorded on 70 hills each of cucumbers and melons, 82.8 percent were on the cucumbers.

In these experiments, eight applications were made between June 14 and July 18, the treatments being applied when considered necessary rather than at regular intervals.

Under these conditions, nine of the eleven materials used reduced the number of beetles on the plants 90 percent or more and three of them gave 100 percent protection on the melons.

Both rotenone dusts and calcium arsenate dusts were effective in reducing the beetle population, the most effective materials being a commercial copper–rotenone dust and a homemade calcium arsenate–fibrous talc dust. Other satisfactory dusts were a commercial stabilized rotenone dust; a commercial calcium arsenate–red copper oxide dust; copper oxychloride–pyrophillite talc 1-14; rotenone–talc (.75 percent rotenone), home mix; and calcium arsenate–pyrophillite talc 1-14. Calcium arsenate–monohydrated copper sulfate–lime 10-20-70 gave good protection against the beetles but caused slight to moderate foliage injury. A tobacco–pyrethrum dust was relatively ineffective and had very little repellent action. An experimental derris spray burned the vines so badly it was discontinued after three applications.

A direct comparison between fibrous talc and pyrophillite talc as a carrier for calcium arsenate resulted in a 5 percent advantage for the fibrous talc, but this slight advantage is not highly significant.

Control of Cabbage Maggot. (W. D. Whitcomb, Waltham.) Because of the cold, wet weather early in the season, the first eggs of the cabbage maggot were not found until May 10, the same date as in 1939, and the latest date in the ten years that records have been made.

The field infestation at Waltham was moderately heavy, averaging 68 percent; but the growing conditions for cruciferous crops were extremely favorable, and in spite of this injury about 53 percent of the untreated plants produced large or medium heads. Only 22 percent of the heads were worthless where no treatment was applied, compared to 49 percent in 1939.

Under these conditions, liquid treatments consisting of corrosive sublimate solution (1 ounce in 10 gallons of water) and calomel–gum arabic suspension (4 ounces calomel and 3¾ ounces gum arabic in 10 gallons of water) gave perfect commercial control of the maggot, and produced 70 to 80 percent large or medium-sized heads.

Because of the cold weather, an application made May 18 (8 days after the first eggs were found) was slightly more effective than a treatment applied May 11 when the first eggs were found.

Calomel–talc dust (4 percent calomel) applied at the same time as the liquid treatments was very effective and produced 80 to 90 percent large and medium heads, being much more satisfactory than in previous seasons.

Root treatments at transplanting were less effective than in 1939 providing 70 to 90 percent control and producing 60 to 80 percent large and medium heads. Pure calomel dusted on the roots gave perfect commercial control of the maggots but produced 36 percent small heads, the greatest number of any treatment, indicating some plant injury.

A direct comparison between fibrous talc and pyrophyllite talc as a carrier for 25 percent and 50 percent calomel used as root treatments favored the pyrophyllite by 10 percent, both in maggot control and in the production of large and medium-sized heads.

Control of Squash Vine Borer. (W. D. Whitcomb, Waltham.) Although the emergence of the squash vine borer moths was 10 days later than normal, the field infestation of 7.45 borers per vine in the experimental field of Blue Hubbard squash at Waltham was the heaviest that has occurred in the last five years.

Experimental control treatments using three dusts and three sprays were applied July 10, 18, 24 and 31. The dusts were applied with a hand duster. For applying the sprays, a hand wheelbarrow sprayer at about 100 pounds pressure was used for the first treatment and a power sprayer at 250 pounds pressure for the other applications.

In spite of the heavy infestation, rotenone-talc dust, a spray of nicotine sulfate 1-500 plus oil emulsion 1 per cent, nicotine sulfate spray 1-250, and copper–rotenone dust all reduced the number of borers per vine 79 percent or more. The differences between these treatments were insignificant, but the greatest protection was obtained from the rotenone–talc dust (.75 percent rotenone) and the spray of nicotine sulfate 1-500 plus oil emulsion 1 percent, with 83.22 and 82.96 percent reduction respectively. A commercial calcium arsenate–copper oxide dust and a commercial rotenone extract spray were not effective.

Yields in the experimental planting were very low owing to unfavorable growing conditions and to a late infection of bacterial wilt. Under these conditions the best yields were obtained where a commercial copper–rotenone dust and a commercial calcium arsenate dust were applied, and it was apparent that the yield was improved more by the fungicidal action of the copper than by maximum control of the squash vine borer.

Control of Onion Thrips. (A. I. Bourne.) Unusually cold, wet weather in April and throughout most of May delayed both planting and germination of onions. In the experimental plots the plants were very late in appearing and made very slow growth until well into July. The abnormally cold, cloudy weather in late June and early July also delayed the appearance of thrips and retarded their development. Many fields of set onions were practically free from thrips up to mid-July when the sets were pulled. The abrupt appearance of hot weather in late July provided conditions more favorable for both the growth of the seed onions and the increase of thrips. In the 10-day period from July 21 to 31, the daily temperature reached 83° F. or higher, and during the 5-day period from

July 26 to 30 the temperature was 90° to 94°. Relatively high humidity accompanied this period of high temperature. Blast appeared in the experimental plots in early August and caused the premature death of the plants. Plants never reached normal height and but few of them bottomed out. Thrips, on the other hand, increased rapidly during late July and early August, scarred the leaves badly, and hastened the effect of blast on the plants.

Field tests were made of a fixed nicotine and SS3 spreader, nicotine sulfate and soap, dual-fixed nicotine and Nufilm spreader, derris (4 percent rotenone) and Ultrawet, derris and Nufilm spreader, and flaked naphthalene which was applied to the soil along the rows.

The fixed-nicotine spray gave good initial control and showed marked residual effect. Derris with Nufilm spreader gave excellent kill and reinfestation was slow. The results were better than when derris was used with Ultrawet as a spreader. Dual-fixed nicotine was not effective. Naphthalene flakes gave too uneven results to be dependable. The nicotine sulfate and soap again proved the most effective of any combination in its initial action, but its residual effects were not so pronounced as those of derris. The early death of the plants, due to blast, before onions were formed made any records on relative yield impossible.

The Spray Residue Problem. (A. I. Bourne.) Effective August 10, the federal spray residue tolerance for apples and pears shipped within the jurisdiction of the Federal Food, Drug, and Cosmetic Act were raised. The tolerance on arsenic as As_2O_3 was raised from .01 to .025 grains per pound of fruit, and that on lead as PbO from .025 to .05 grains per pound. This ruling does not apply to fluoride compounds, on which the tolerance of .02 grains per pound is still in force. Neither does the present ruling extend to other food commodities than apples and pears.

The newly defined limits of tolerance are based on extensive studies by the Public Health Service and upon the recommendations of that body. This action brings a great measure of relief to many growers who have been confronted with increasing demands for more extensive spray programs to cope with increasing abundance of major pests such as apple maggot and codling moth, in the face of more and more stringent enforcement of regulations on tolerance.

Through the cooperation of the Chemistry Department, analyses of samples of McIntosh from the experimental orchards showed both lead and arsenic residues to be well below the present requirements. Samples from plots receiving the standard schedule of lead arsenate and lime-sulfur in pre-blossom and calyx applications and lead arsenate and wettable sulfur in the cover sprays showed the presence of .006 grains of As_2O_3 and .011 grains of PbO per pound of fruit. Fruit from plots receiving lead arsenate and wettable sulfur throughout the season showed .004 grains of As_2O_3 and .011 grains of PbO per pound. Lead arsenate at dosages of 4 pounds (2d cover), 3 pounds (3d cover), and 2 pounds (4th cover) per 100 gallons was applied on June 28, July 9, and July 22, respectively. The fruit was harvested September 27 and 28. During this period there was very slight rainfall, especially in August and September when the combined precipitation for the two months was less than half the normal. Even under these conditions the margin of safety was such that no washing or wiping of fruit was necessary to meet the present tolerances.

Studies of the value of fixed nicotine in late-season applications for codling moth control, as a supplement to the present spray schedule, were continued in the same commercial orchard as in 1939. Codling moth was reduced to such low proportions in 1939 that banding was discontinued in 1940. Two applications of fixed nicotine were made in addition to the regular schedule: the first in late July in substitution for the regular 4th cover spray, and the second in mid-August.

Based on the examination of McIntosh at harvest, codling moth damage was reduced to 1.09 percent on trees in the center of the orchard, and to 3 percent on border trees exposed to migration from nearby orchards. Similar records of Northern Spy showed 2.6 percent injury on trees in the center of the block and 4.7 percent on marginal trees. The damage on Rhode Island Greening was reduced to 1.4 percent. The control secured on Northern Spy was of particular interest. In 1936 codling moth injury to fruit in that block was estimated at 75 to 80 percent of the crop and was the principal reason for undertaking the test in that orchard. This was the first opportunity of checking the value of the control program on that variety, since Northern Spy is a biennial bearer and the crop of 1938 was strewn about promiscuously by the hurricane of that year.

Apple Maggot Control. (A. I. Bourne and W. D. Whitcomb.) Inspection of fruit at harvest and reports from growers indicate that very generally over the State this pest was somewhat more abundant than in 1939 and appears to be building up an infestation to serious proportions. Several factors have produced conditions favorable for such increase. In 1937, as a result of low prices, many growers failed to harvest much of the early-maturing fruit and neglected to dispose of dropped apples promptly. In the following year the hurricane disrupted normal harvesting of the fruit and much of it was left in the orchards. In 1939, as a result of the diversion features of the Surplus Commodity Program, much fruit was left under the trees. This combination of circumstances supplied conditions very favorable for apple maggot development and explains in great measure why this pest is proving so troublesome in many of the better-cared-for orchards of the State.

Emergence of apple maggot flies in cages at Waltham was the smallest that has been recorded for several years. In these cages the time of emergence was 4 or 5 days earlier than in 1939. The record is as follows:

Percent Emerged	In Sun—Light Soil	
	Cultivated	Sod
First fly	June 25	June 30
25%	July 3	July 6
50%	July 9	July 9
75%	July 15	July 15
100%	July 25	July 26
Total	126	121
% emerged	25.4	24.2

Insecticides for the Control of European Corn Borer. (A. I. Bourne and W. D. Whitcomb.) The cold, wet weather which characterized most of the spring seriously interrupted the seasonal program of many growers, delayed planting, and retarded growth of the crops. In many cases corn was planted later than usual and made very slow growth after germination. Early June was comparatively warm and stimulated the development of both the corn and the European corn borer. In Amherst and vicinity moths began to appear during the first week of June and by the 14th larvae appeared, approximately a week later than in 1939. The first sprays were applied on June 17.

Field tests of different insecticides for corn borer control were made in cooperation with the same growers as in the previous years. The variety used was Golden Early Market, the same as in 1939, and the plantings were made on approximately the same date. The late season, however, delayed growth so that the plants were much smaller than usual at the time the first spray was applied, and a schedule of 5 applications at 5-day intervals was followed. The month of June closed with a 10-day period of some of the coldest weather on record for that time of year, and practically the same condition prevailed in early July. The corn made very slow growth and was not ready to harvest until August, nearly two weeks later than normal. Derris spray (4 percent rotenone content), derris dust (1 percent rotenone), dual-fixed nicotine dust, dual-fixed nicotine as a spray (nicotine content equivalent to nicotine tannate), and commercial prepared rotenone sprays were used in the tests. Apparently one by-product of an otherwise unfavorable season was a comparatively light infestation of corn borer. Yield records showed corn in the check plots to be 85 percent free from borers. Derris spray gave 97.8 percent clean ears, and derris dust 96 percent; dual-fixed nicotine as a dust gave 97.6 percent clean ears and as a spray 96+ percent. Only 77 percent of the yield in the check plots, however, was of marketable grade; while in the plots treated with derris spray 89.8 percent of the crop was marketable, with derris dust 79 percent, with dual-fixed nicotine dust 82 percent, and with dual-fixed nicotine spray 81.7 percent—a very favorable comparison with unsprayed corn even in a year of light infestation. The derris spray gave a reduction of 95.5 percent in borer population in the stalks as compared with the unsprayed checks, derris dust 92.5 percent, dual-fixed nicotine dust 87.9 percent, and dual-fixed nicotine spray 75 percent.

Studies of the relative effectiveness of different strengths of derris, in the Experiment Station plots, encountered the same difficulties mentioned above—unfavorable weather conditions and very slight infestation by the borer. The results indicated that a dosage of 2 pounds of derris (4 percent rotenone content) per 100 gallons was not sufficient for dependable control, and that a dosage of 6 pounds to 100 gallons did not give sufficient difference in control over the 4-pound strength to warrant the extra cost.

In tests of Bancross 39 sweet corn at Waltham, five applications (June 17, 22, 27, July 2, 12) of powdered derris root 3 pounds and Ultrawet 8 ounces in 100 gallons of water produced a gain of 16 to 20 percent in the number of ears free from injury by the first generation of the corn borer. The ear infestation in the unsprayed plot was 22.46 percent, while that in the sprayed plot was 2.67 percent where a 2-nozzle spray rod was used and increased to 6.01 percent where an orchard spray gun was used. At a cost of $1.80 per plot for spray materials, the sprayed plots produced approximately 350 and 300 ears more than the unsprayed plot.

A similar experiment was made to control the second generation of the corn borer on late sweet corn, using Carmelcross seed sown on June 21. Three applications of derris spray were made, on August 16, 21, and 27, and records were taken on September 11 when the ears were harvested. The results showed no value for spraying, the percentage of non-salable ears due to borer being 13.99 unsprayed and 14.82 sprayed. The records clearly show that more than three applications are necessary even if they are continued nearly to harvest, since most of the infestation in the sprayed corn was from recently hatched borers. The results were further confused by a heavy infestation of corn ear worm which did not appear to be affected in any way by the sprays.

Potato Spraying Experiments. (A. I. Bourne.) Cold, wet weather during spring and early summer, which prevented planting at the usual time, delayed the appearance of the plants and retarded growth; subnormal rainfall which persisted through August and September and an early frost on September 25-26, which killed the plants in all plots, combined to form a sequence of unfavorable weather conditions unusual even for New England.

The experimental plots were planted on May 21 but young plants did not appear until well into June. On the east half of the plot the stand was very light with many "skips" so that a considerable area had to be discarded as useless for experimental purposes. Plants in all plots were green and still making growth when killed by the frost of September 25.

During the early season the infestation of fleabeetles was comparatively light and little damage was done. The attack in late July, however, was very heavy and there was considerable damage to unprotected foliage. Leafhoppers appeared late in the season and were not very numerous. A heavy infestation of potato aphids was encountered in late July and early August. In many fields in the Valley the abundance of aphids led to the greatest build-up of several species of Coccinellid beetles which has been observed for many years. In the experimental plots incipient outbreaks were checked by the use of nicotine in the sprays applied July 31 and August 7. In the test plots, 12 applications were made between June 20, when the plants were 3 to 4 inches high, and September 4 when the flea beetles and leafhoppers disappeared. Vines were killed by frost on the night of September 25–26, and the potatoes were dug October 1 to 3.

Weekly counts of flea beetle injury showed practically no difference in degree of protection from 5-2½-50 and the standard 5-5-50 bordeaux mixture. The addition of calcium arsenate in both mixtures, however, materially reduced the amount of damage, especially in the plots receiving low-calcium bordeaux. The growing season was three to four weeks shorter than normal because of the late appearance of the plants in the spring and the early frost in September. This was reflected in the yields. Records of comparative yield in the different plots were of little significance since plants in all plots were prematurely killed by the frost.

Tests of commercial materials included applications of a commercial basic copper arsenate–wettable sulfur, a basic copper–wettable sulfur combination, and a yellow copper oxide–Cherokee clay combination at dosages of 1½ and 1 pound of the copper oxide per 100 gallons of spray. Against flea beetle feeding both the basic copper–sulfur combinations gave excellent protection, fully as good as that given by the standard bordeaux with calcium arsenate added. The yellow copper oxide sprays furnished protection equivalent to standard bordeaux without arsenical.

Records at harvest showed that plots treated with the commercial sprays yielded approximately 350 bushels per acre, which was only slightly less than the yield in the standard bordeaux plots. It is probable that greater differences would have existed if early frost had not intervened, since the plants in these plots were beginning to change color and die down while throughout the bordeaux plots the plants were still green.

Introduction of Parasites of Oriental Fruit Moth in Peach Orchards. (A. I. Bourne.) This service, requested and financed by peach growers of the State, was continued in 1940, and more than 30,000 *Macrocentrus ancylivorus* were liberated in the orchards. Through the cooperation of the Department of Entomology of the Connecticut Experiment Station, Mr. A. DeCaprio was again secured to take immediate charge of this work from June 1 to July 15. More than 80 colonies of *Macrocentrus* parasites were released in the orchards of 63 growers in 9 counties of the State. Several of the county agents assisted in the release of the parasites and enabled the work of liberation in the orchards to be done with greater dispatch than would otherwise have been possible. As a result of the efficient work of Mr. DeCaprio in the collection of breeding material in New Jersey and improved technique in the laboratory, the percentage of emergence was so very high that it was possible to supply parasites for all advance orders and furnish to the county agents enough colonies to duplicate orders. The Laboratory also supplied colonies to Dr. Christopher, extension horticulturist of Rhode Island State College, for the peach growers of that state on the same terms extended Massachusetts growers. Many growers availed themselves of the offer made this year to furnish colonies in two containers. This allowed, in separate blocks or different parts of the same orchard, distribution of parasites with the proper proportion of sexes for satisfactory colonization.

During the period when the parasites were liberated weather conditions were favorable for their activity, and little or no mortality was noted.

Naphthalene and Similar Compounds as Greenhouse Fumigants. (W. D. Whitcomb and Wm. Garland, Waltham.) A complete series of thirty experimental fumigations of potted carnations was made, using a mixture of chlornaphthalene oil 3 parts and crystal naphthalene 1 part, at the rate of ½ ounce per 1,000 cubic feet for 6 hours.

One treatment gave complete control of the common red spider (*Tetranychus telarius* L.) at a controlled constant temperature of 80° F. and constant relative humidities of 80 or 90 percent. At temperatures of 60° and 70° F., and relative humidities of 80 and 90 percent, the mortality of red spiders ranged from 80 to 90 percent; while at 50 percent relative humidity the mortality varied from 50 to 83 percent.

After two successive fumigations, complete mortality resulted at 50 percent relative humidity with a constant temperature of 80° F.; at 60 percent humidity with constant temperatures of both 70° F. and 80° F.; and at 70 percent humidity or higher at all three temperatures.

These results were obtained only when the controlled temperature and relative humidity were maintained throughout the entire period of exposure.

Control of the Common Red Spider on Greenhouse Plants. (W. D. Whitcomb, Wm. Garland, and W. E. Tomlinson, Jr., Waltham.) Life-history studies under controlled conditions indicated that female red spiders (*Tetranychus telarius* L.) on carnations developed from newly hatched larvae to adults in 16.91 days at 60° F., 10.22 days at 70° F., and 6.07 days at 80° F. The same development took approximately one day less on sweet pea and one-half day less on snapdragon than on carnation. This difference was consistent at constant temperatures of 60°, 70°, and 80° F. As observed in previous studies, the developmental period at 60° F. was about three times longer than at 80° F.

In spraying experiments on roses in greenhouse benches using 8 different commercial rotenone preparations, the addition of a neutral copper fungicide decreased the efficiency of the insecticide against the red spider about 5 percent in those materials consisting primarily of rotenone and emulsifier. However, in those preparations in which rotenone was combined with other insecticidal ingredients such as thiocyanate or light mineral oil, the additon of a neutral copper fungicide had no significant effect on the red spider mortality.

In these experiments satisfactory control was obtained after four applications at weekly intervals only with those materials which contained some insecticidal ingredient in addition to rotenone and emulsifier. According to counts made 3 to 5 days after each of four applications at weekly intervals, only those sprays which caused a mortality of 50 percent or greater prevented the spider population from increasing during the spraying period; and in some cases where the population was held in check during the spraying period, it increased so rapidly after spraying was discontinued that within one week the infestation was greater than after the first application.

Many of these commercial sprays were more effective at concentrations two to three times greater than recommended by the manufacturers.

Preliminary experiments on potted rose plants gave promising results from a mixture of tartar emetic, brown sugar and wetting agent, but it was ineffective when the brown sugar was omitted. Indications of plant injury from this material were observed.

A dinitro dust was very toxic to red spider on both rose and carnation but caused some injury to rose foliage.

Biology and Control of the Apple Leaf Curling Midge. (W. D. Whitcomb, Waltham.) The apple leaf curling midge, (*Dasyneura mali* Kieff.) was generally more abundant than in 1939 and the known infested area was increased to the west and southwest by the discovery of this insect at Ashby and Westboro, Massachusetts.

In the insectary only one midge fly emerged from 325 maggots which were collected in June, July, and August 1939 and overwintered in sand, but flies emerged in 1940 from 8 to 36 percent of the maggots which were collected in September 1939 and held over winter in the same way. The transformation to flies was 42.42 percent from the maggots collected in June; 27.6 percent from those collected in July; and 13.33 percent from those collected in August.

The orchard infestation at Westford, Massachusetts, as indicated by the percentage of terminal buds on which eggs were laid, began May 24 and reached three distinct peaks on June 4-7, July 16-19, and August 23, when eggs were found on 99 to 100 percent of the buds. After June 25 practically all new growth is on watersprouts, and on trees where watersprouts are limited the actual number of eggs is relatively small even though the percentage of buds infested is high. After August 25 only one or two growing tips suitable for ovipositon by the midge flies could be found on a tree.

The emergence of maggots from rolled leaves was concentrated in two distinct peaks, that of the first generation larvae occurring on June 25 and that of the second generation larvae reaching a maximum on August 2 but being spread out over the period July 20 to August 9. Emergence in large numbers occurred only when accompanied by sufficient precipitation to thoroughly soak the leaves.

The average number of eggs per female midge fly as determined by dissection of 12 gravid adults of the second generation was 155.5±6.66, varying from 102 to 216.

Infested apple buds during the oviposition period of the first generation flies averaged 318.1±13.47 eggs per bud, varying from 198 to 404.

Applications of naphthalene flakes broadcasted under the trees reduced the number of flies of the overwintering generation emerging in cages by 83.4 percent where 1 pound of naphthalene per 100 square feet was applied, and by 80.9 percent where 2 pounds was used. The emergence of the first generation flies under similar conditions was reduced 75.42 percent by 1 pound of naphthalene and 93.31 percent by 2 pounds. The emergence from the untreated ground was 3.56 overwintering generation flies per square foot and 22.87 first generation flies per square foot. Emergence of flies from duff (dried leaves, hay, etc.) collected in the experimental orchard and caged in the insectary was none from duff treated with 2 pounds naphthalene per 100 square feet compared to 28.5 flies of overwintering generation per pound of untreated duff, and 3.69 flies of the first generation per pound of naphthalene-treated duff compared to 78.46 flies per pound of untreated duff.

Preliminary laboratory experiments with dormant sprays on apple bark containing an unknown number of overwintered midge cocoons showed no survival where dinitro sprays were applied, and a small survival where oil emulsion was applied or no treatment was given. These results were inconclusive but offer some encouragement for control by dormant sprays applied to the bark.

Control of Plum Curculio in Apples. (W. D. Whitcomb, Waltham.) The critical period of curculio activity in 1940 began on June 1, five days after the normal petal fall stage, and continued to June 7. During this period, sprays consisting of lead arsenate 4 pounds, wettable sulfur 4 pounds, and fish oil 1 pint, were applied to certain trees when the apples of each variety were approximately 4/16, 5/16 and 6/16 of an inch in diameter, as determined by measurements with calipers. The examination of 128,888 apples resulted as follows:

Variety	Size of Fruit (Inches)	Date Spray Applied	Apples Stung (Percent)
Gravenstein	4/16	June 1	20.18
	5/16	June 3	9.95
	6/16	June 5	33.28
McIntosh	4/16	June 4	7.08
	5/16	June 5	3.08
	6/16	June 7	8.35
Baldwin	4/16	June 1	4.80
	5/16	June 3	3.22
	6/16	June 5	6.14
Wealthy	4/16	June 3	5.55
	5/16	June 4	11.19
	6/16	June 5	15.13

The most effective sprays on Gravenstein, McIntosh and Baldwin were applied when the apples were approximately 5/16 of an inch in diameter and on Wealthy at the 4/16 inch size. It is also evident that the most effective spray was applied June 3 at which time the maximum temperature and greatest curculio activity of the period occurred, and that the high temperature stimulated both curculio activity and growth of apples. One timely spray during the critical period is satisfactory on McIntosh, Baldwin, and Wealthy but not on Gravenstein. On Gravenstein and Baldwin the percentage of curculio-stung apples was from 50 to 100 percent greater on the dropped apples than on the harvested apples, but on McIntosh and Wealthy the injury was 5 to 10 percent greater on the harvested fruit.

A growth of 1/16 of an inch in diameter of an apple represents an increase in surface area of 156 percent, and since this growth may occur in 24 hours, timeliness in the application of a spray is important.

Biology and Control of the Grape Plume Moth and Grape Cane Girdler.

(W. D. Whitcomb and W. E. Tomlinson, Jr., Waltham.)

Grape Plume Moth. Life history studies of the grape plume moth showed that larvae hatched from 57.89 percent of the eggs which were overwintered on potted grape vines, and that all hatching occurred in the three-day period, May 14–16. The feeding period of larvae averaged 39.2 days and the pupation period 16.37 days, making a developmental period from hatching to adult of approximately eight weeks. Because of cool weather, this period was about two weeks longer than in 1939.

On heavily infested vines the number of overwintering eggs averaged 3.36 per foot of cane, or 3.18 eggs per node. Since each node ordinarily produces a shoot, this infestation is equivalent to about 3 insects for each growing shoot.

Laboratory experiments with commercial dormant spray materials gave complete mortality of eggs with lubricating oil emulsions containing 3 or 4 percent actual oil, and 90 percent mortality or higher with 1 or 2 percent actual oil in the diluted spray. Lime sulfur 1-8 gave 80 percent mortality of the eggs. Sodium dinitro cresylate was effective when diluted to 1 and 1¼ percent, but at dilutions of ½ and ¾ percent only 48 percent mortality resulted. On unsprayed canes, 63 percent of the larvae hatched.

Field experiments in home vineyards showed 80.4 percent protection where lubricating oil emulsion diluted to contain 3 percent actual oil was used, and 72.86 percent where ¾ percent sodium dinitro cresylate was used. On unsprayed vines 84.12 percent of the tips were infested. In another experiment where 58 percent of the tips on unsprayed vines were infested, treatment with ½ percent sodium dinitro cresylate gave 92 percent protection, and lime sulfur 1-8 gave 11 percent protection.

Spraying on May 1 when the buds were breaking and about one week before the larvae hatched, using lead arsenate and fish oil and lead arsenate combined with Bordeaux mixture, failed to give protection.

Grape Cane Girdler. Emergence of the grape cane girdler beetles from hibernation and their appearance in the vines occurred when the new canes were about 6 inches long. They also appeared to be stimulated by high temperatures to the same degree as the plum curculio. Mating occurs soon after the beetles leave hibernation and the first girdled canes were observed June 2.

On potted grape vines in the insectary, mated beetles averaged 3.13 oviposition punctures per female, but observations indicate a greater oviposition activity in the field. The average life of 27 individuals reared in the insectary from oviposition to adult was 54.55 days.

When burrowing in the cane, most of the larvae work toward the base of the cane rather than toward the tip, and when control by hand picking is practiced, the infested cane should be removed well below the lowest girdle.

Spraying experiments with cryolite and fish oil gave moderate protection, but during the most rapid growth of the grape canes applications at weekly intervals permitted considerable girdling between treatments.

Parasites of the European Earwig. (W. D. Whitcomb, Waltham.) In order to follow up the liberation of parasites in the Fall River–Taunton area in 1939, twenty earwig traps or hiding blocks were placed in June 1940 in the localities where parasites had been released. These were examined in July, August, September, and October, but no specimens of the earwig parasite, *Bigonichaeta setipennis,* were recovered.

The earwig population throughout the infested area was less than in 1939, especially in Fall River where the number recovered in traps was 78 percent less. In the Somerset—Taunton area, the number of earwigs captured was 26 percent less than in 1939.

Insects Concerned in the Dispersal of Dutch Elm Disease. (W. B. Becker.) Mr. W. E. Tomlinson, Jr., at the Waltham Field Station again cooperated by continuing experiments with the native elm bark beetle and the smaller European elm bark beetle. The following data were taken.

The Native Elm Bark Beetle, Hylurgopinus rufipes (Eich.). In the logs (mentioned in last year's report, page 66) from hurricane-felled trees in which eggs were laid in early June 1939 and from which adults began to emerge on July 29, 1939, emergence was observed to continue until November 3, 1939. No emergence was observed from these logs during 1940.

The Smaller European Elm Bark Beetle, Scolytus multistriatus Marsham. In the logs (mentioned in last year's report, page 66) from hurricane-felled trees in which eggs of this species were laid in early June 1939 and from which adults began to emerge on July 20, 1939, the emergence was observed to continue until September 10, 1939. Emergence was again observed from these same logs on June 5, 1940, and continued until July 22, 1940, (173 beetles emerged during 1939 whereas 883 emerged during 1940 from the same caged material).

Scouting for Elm Bark Beetles. (W. B. Becker.) In conjunction with Dr. D. O. Wolfenbarger of the Dutch elm disease laboratory at Morristown, New Jersey, scouting for *Scolytus multistriatus* was carried on in various parts of Massachusetts, especially in places where spread was most suspected. Adult beetles were found in Western Massachusetts at Richmond Furnace, Stockbridge, West Stockbridge, and Monterey, and in eastern Massachusetts at Marlborough and East Pepperell—all locations where they had not been previously found.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (Harold E. White, Waltham.) Back-crossing and selection work is being continued with the Field Station rust-resistant strains. Greenhouse varieties of snapdragon, Lucky Strike, Afterglow, New Cincinnati, Laura, Cheviot Maid, Rose Orange, Bronze Queen, Cornwallis, and Rose Queen, were observed to be very susceptible to rust disease under field conditions. When such varieties were intercrossed, the progeny of the F_1 and F_2 generations continued to show a high degree of susceptibility to rust. However, the F_3 generation selections, particularly from a cross between Lucky Strike and Afterglow, showed definite resistance to rust disease. This is an unusual situation in that the existence of natural resistance in susceptible commercial varieties of snapdragons has not been definitely proved. The explanation offered for this type of resistance to rust is that these varieties must carry modifying genetic factors which, under conditions of intercrossing and inbreeding, permit a more complete expression of the resistance factor. The nature of this type of resistance and the extent to which it can be developed by breeding must be determined by further work.

Wilt disease (Verticillium) continues to be destructive to snapdragons in the field, though of rare occurrence under greenhouse conditions.

Effect of Plant Nutrients, Soil Reaction, and Light on Gardenias. (Harold E. White, Waltham.) Previous experiments were concerned with the effects of different nitrogenous fertilizer materials on flower production, bud drop, and iron chlorosis. This type of work has been continued with three phosphate fertilizer materials to determine whether readily available phosphoric acid, as compared to less available forms, had any specific effect on growth of gardenia plants. Additional phosphoric acid in the form of bone meal, precipitated bone, and superphosphate (16 percent), applied to soils in sufficient quantities to supply 320 pounds P_2O_5 per acre, affected flower production appreciably.

Yields on untreated plots were 20.16 flowers per plant; on plots receiving precipitated bone, 22.39; bone meal, 20.91; and superphosphate, 17.19 flowers per plant.

Bud drop was perceptibly greater on plants given organic forms of phosphoric acid. Untreated plants showed 33.88 percent bud drop; those receiving applications of precipitated bone showed 34.70 percent; bone meal, 39.40 percent; and superphosphate, 29.30 percent bud drop.

Symptoms of chlorosis due to a lack of iron were definitely more severe on plants that received superphosphate than on those given either bone meal or precipitated bone.

Cultural Requirements of Freesias. (Harold E. White, Waltham.) Freesia corms dried or precured for 28 days and planted September 14, 1939, required 155 days to reach the flowering stage, as compared to 165 days for untreated corms planted on August 17. Corms dried for 9 weeks and planted October 19 flowered in 130 days. The number of days necessary for Freesias to reach the flowering stage decreased in proportion to the lateness of planting, but the actual date of bloom was not affected by precuring treatments. Corms untreated and planted August 17 bloomed on an average of two weeks sooner than precured corms. The plant growth and productivity of the corms were not affected by precuring treatments prior to forcing.

Freesias subjected to constant temperatures of 50°-52° F. during the rooting period after precuring were not affected favorably or unfavorably by such a treatment. Corms precured at temperatures of 45°-46° F. in a refrigerator for 1 to 4 weeks did not flower any sooner that those given a warm storage treatment.

Treatments of precuring for 1 to 11 weeks prior to forcing resulted in a loss in dry weight of the corm to the extent of 1 to 24 percent, but there was no correlation between losses in weight and forcing characteristics of the corms.

The data presented were on the variety Purity. Tests in progress with the variety Daffodil indicate that possible varietal differences may exist.

These responses of Freesias to precuring treatments were obtained with forcing temperatures of 52°-55° F.

Soilless Culture of Florists' Crops. (Harold E. White, Waltham.) Marigolds, calendulas, poppies, snapdragons, stevia, sweet peas, carnations, roses, and gardenias were grown in cinders in comparison with soil. The annual type of flowers responded quite satisfactorily to culture under soilless conditions.

Rose plants of the variety Chieftain produced an average of 16.43 flowers per plant compared to 21.37 blooms in cinders. There was 77.18 percent of flowers with 12-15 inch stems from soil-grown plants as compared to 82.45 percent from plants grown in cinders. The gain in production of 12-15 inch grades from plants in cinders was 5.27 percent.

With the variety Talisman, flower production was greater from plants in soil, 25.68 blooms per plant in comparison with 23.75 blooms per plant in cinders. However, on a grading basis Talisman plants in soil produced 79.32 percent of flowers with 12-15 inch stems as compared to 82.90 percent in cinders. The gain in production of 12-15 inch grades was in favor of cinder-grown plants to the extent of 3.58 percent.

Sweet peas sown in August in soil in a raised bench produced twice as many flowers as plants grown in cinders. Sweet pea blooms from plants in cinders were superior to those from plants grown in soil. There was a much more pronounced stimulation of vegetative growth of the sweet pea plants grown in cinders than of soil-grown plants.

Carnations responded very poorly to culture in cinders and production was inferior to that of plants in soil. However, the plants available for use in the cinders were of poor quality which may be an explanation for the poor results obtained. At least, the results would indicate that weak, inferior plants cannot be expected to respond any more satisfactorily under soilless culture methods than they would in soil.

Carnation plants growing in cinders or gravel were successfully fumigated with naphthalene compounds for the control of red spider. Fumigations were made without flooding the benches with water.

One observation in a commercial range on the use of naphthalene fumigants on carnations in gravel indicates that injury can occur. In this particular case burning of the plants occurred under soil conditions as well as on plants in gravel; apparently fumigation conditions as related to temperature, humidity, or rate of vaporization were not properly controlled. Burning of the foliage was more severe on plants grown in gravel and a greater percentage of bud injury occurred. However, the plants in gravel made a more rapid recovery from the injury than did plants grown in soil; this was evidenced by vegetative growth response on the plants.

Gardenias did not respond favorably to culture in cinders. The chief difficulty experienced was getting the plants to take up sufficient iron to maintain normal growth. Plants which became quite chlorotic from a deficiency of iron never satisfactorily recovered even after considerable manipulation of the nutrient solutions.

Banana Stalk Fiber as a Source of Organic Matter for Soil Improvement. (Harold E. White, Waltham.) Crushed banana fiber is a waste or by-product which has been marketed by the Meloripe Fruit Company of Boston for several years. The value of this material for use as a mulch on plantings of shrubbery and market garden crops has been demonstrated previously at the Waltham Field Station.

In recent tests shredded banana fiber composted with soil for 10 to 12 months has been found satisfactory for use in the greenhouse culture of carnations and snapdragons. Banana fiber, as determined by analyses, is relatively high in carbonates of magnesium and potassium and, therefore, is alkaline in reaction. Such a material would be most satisfactory with a soil that is too acid, but if used on soil with a low lime requirement, the liming value of the banana fiber should be taken into consideration

Cultural comparisons were made between ordinary stable manure, spent mushroom manure, and the banana fiber. The banana fiber and mushroom manure were found to have a toxic effect on gardenias, causing iron chlorosis. This was probably due to the high lime content of the materials. Therefore, they should not be used on crops which have a low lime requirement, or they must be leached well with water to remove most of the soluble carbonates.

Liming Carnation Soils. (Harold E. White, Waltham.) Carnation plants of the variety New Deal Ward, grown in a soil that received no lime, produced 23.40 flowers per square foot. When lime was applied to the same type of soil at the rate of 1 ton per acre, the carnation plants produced 21.10 flowers per square foot; 1½ tons yielded 22.40 flowers; 2 tons, 20.10 flowers; and 3 tons, 21.30 flowers per square foot.

The percentages of flowers with split calyces produced by plants in the various treatments were: unlimed, 21.50 percent; 1 ton of lime, 23.20 percent; 1½ tons of lime, 24.70 percent; 2 tons of lime, 22 percent; and 3 tons of lime per acre, 25.60 percent. The average acidity test of the soil prior to liming was pH 5.6. At the termination of the experiment, soil tests on the untreated and treated plots were: No lime, pH 4.6; 1 ton of lime per acre, pH 5.3; 1½ tons, pH 5.7; 2 tons, pH 5.9; 3 tons, pH 6.4.

Plant losses from soil-borne disease organisms such as root, stem and branch rot were very low. There appeared to be no correlation between limed and unlimed soils as to the prevalence of diseased plants.

Packet Seed Studies. (Clark L. Thayer.) For a fifth season the Department of Floriculture has cooperated with the Seed Laboratory in a test to determine the quality of flower seeds sold in retail seed stores, garages, hardware stores, groceries, schools, and other retail outlets. The seeds, which were collected by a representative of the State Commissioner of Agriculture, were tested for germination and performance under field conditions.

The test included 194 lots, representing 46 genera, packeted by 32 wholesale establishments, and obtained from 53 retail outlets. Records on germination showed 146 lots, good; 30 lots, fair; 16 lots, poor; 2 lots, none. Records on performance showed 155 lots, satisfactory; 6 lots, fair; 33 lots, not satisfactory. Detailed results are reported in Control Series Bulletin 107.

DEPARTMENT OF HOME ECONOMICS NUTRITION

Helen S. Mitchell in Charge

Vitamin Requirements of Older People. (H. S. Mitchell and A. W. Wertz.) Scientific knowledge regarding the chemical nature and physiologic function of vitamins has progressed by leaps and bounds in recent years, but knowledge regarding the human requirements for the different vitamins has not kept pace with other phases of vitamin research. The vitamin requirements of young adults, college students, and children have been studied to a limited extent and more with regard to vitamins A and C than any others. Little, if anything, is known regarding the vitamin requirements of older people or the vitamins most significant in the maintenance of optimum health with advancing years. Thiamin seems to be the one most apt to be deficient.

Reports from various parts of the country, mostly in the medical journals, indicate that thiamin (vitamin B_1) administered in liberal dosage has brought about considerable improvement and in some cases complete relief from various chronic complaints and discomforts commonly associated with and accepted as inevitable accompaniments of old age. A question as to why increased need for thiamin should become evident in middle age has never been answered. Minor changes in food habits may decrease the amount of vitamin consumed; metabolic changes may increase the need; or chronic infection may destroy or use extra vitamin, thus depriving the body of its normal supply. Thus it is proposed to ask the cooperation of a limited number of people living in Amherst to help us in the study of the thiamin requirements of reasonably normal people in the seventh and eighth decades of life. Such an experiment is possible only where intelligent and scientifically minded people are willing to give their interest and support to the project.

A few years ago it would have been impossible to propose a study of this kind because so little was known concerning the function of thiamin in the body. Today we know that the body cannot store thiamin to any extent and that the excess beyond what we need is excreted in the urine unchanged. A small excess of the vitamin can do no harm. If the body has received less than its normal requirement for some time, it will temporarily store thiamin in the tissues, when given a chance, until its quota is filled. If there has been no deficiency, the excess vitamin ingested will be excreted promptly. Thus the need of the body can be studied by measuring the excess excreted in the urine after the need of the body has been satisfied.

Another reason why a study of this kind can be undertaken today better than earlier is the improvement in methods for estimating thiamin quantitatively. Until recently we were dependent upon animal feeding tests which were tedious and expensive. Today there are two or three chemical methods available and also a yeast fermentation method. Yeast cells require thiamin in order to grow and cause sugar to ferment. The latter method is suitable for the determination of thiamin in urine and is the one we are using.

The subjects who participate in this study will be contributing both to scientific knowledge and to their own well-being, we hope. Each subject will be expected to submit to a complete physical examination by a cooperating physician. Subjects will not be expected to alter their usual food habits or disrupt their daily routine in any way. They will be asked to keep a record and furnish us with a list of foods eaten for a week or more preceding and during certain tests. Any medicines, laxatives, vitamin supplements, etc., will need to be recorded. Subjects will be asked to collect accurate 24-hour urine specimens. The plan of the experiment will be to study first the usual amount of thiamin excreted by each subject on his habitual diet without vitamin supplement of any kind. After this preliminary study, carefully graded doses of thiamin will be prescribed.

This project was started in the fall of 1940 and is being sponsored partially by Standard Brands Incorporated.

Cause and Control of Nutritional Cataract. (H. S. Mitchell, G. M. Cook and A. W. Wertz.) The experimental production of cataract in rats by feeding rations containing galactose has become a means of studying the effect of other dietary factors upon the lens. The susceptibility of this delicate tissue to injury from foreign substances as galactose in the blood stream is materially reduced by a liberal amount of protein in the ration. Whether protein or some nitrogenous substance might be protective against lenticular injury due to other causes than galactose is not known. The nature of the protein or of the protein constituents which might exert this protective action have been the subject of further study, and reports have been published as follows:

1. *The Anti-Cataractogenic Action of Certain Nitrogenous Factors.* (H. S. Mitchell, G. M. Cook, and M. D. Henderson. Arch. Ophth. **24,** 990-98, 1940.) Data presented in this paper confirm earlier reports that inadequate protein (5 percent) aggravates and that high protein (45 percent) inhibits the development of cataract in rats fed galactose. Attention was then turned to the investigation of certain nitrogenous factors. An enzymic hydrolysate of casein gave the same degree of protection as its nitrogen equivalent in commercial casein. Cystine (2 percent) and methionine (2 percent) gave only slight or irregular protection. Moreover, when the sulfhydryl amino acids were made less available by the addition of 100 mg. of iodoacetic acid or 250 mg. naphthalene to 100 g. of ration, growth was retarded but cataractous changes were not hastened. Urea at 1, 5, and 10 percent levels gave less protection than an equivalent of N fed as protein. Choline was studied by adding 1, 2, 4, and 8 percent to a 5 percent casein ration. Growth was progressively poorer the higher the level of choline fed and there was no protection against cataract.

2. *The Effect of Dry Heat Upon the Anti-Cataractogenic Quality of Certain Proteins.* (M. D. Henderson and H. S. Mitchell. J. Nutri. **21**, Feb. 1941.) The knowledge that protein exerts protective action against galactose injury in rats, raises the question as to whether the type of treatment which is known to decrease the growth value of a protein will also affect its cataract-inhibiting quality. The four proteins—casein, egg albumin, wheat gluten, and beef fibrin—were fed as purchased and after being

exposed to dry heat for 96 hours at 125° C. These proteins were then incorporated into a 25 percent galactose ration in amounts to furnish 15 percent of protein. The ration was entirely adequate in other factors.

The growth value of these proteins was damaged by heat in the decreasing order: gluten, casein, fibrin, egg albumin. The anti-cataractogenic property was reduced by heating in the decreasing order: casein, egg albumin, gluten, fibrin. Thus these two properties of protein were not damaged to the same degree by exposure to dry heat. It follows that, if the protective factor is an amino acid or group of amino acids, they are not necessarily the same as those essential for growth.

The blood-sugar values tended to be higher in the rats fed heated casein than in the plain casein groups but were not significantly different for the other proteins before and after heating. It would appear that the degree of galactemia cannot alone account for the difference in the degree of lenticular injury observed. Thus it seems that the protein factor may be protective in the presence of the high blood galactose.

3. *The Effect of the Hydrolytic Products of Casein and Deaminized Casein on the Cataractogenic Action of Galactose.* (E. L. Moore, M. D. Henderson and H. S. Mitchell. J. Nutri. **21,** Feb. 1941.) (Department of Chemistry cooperating.) Preliminary work showed that deaminized casein was more protective against galactose cataract in rats than ordinary commercial casein from which it was prepared. Other work has indicated that the type of treatment which alters the growth value of a protein may or may not affect its anti-cataractogenic quality. Hydrolytic products of casein and deaminized casein were prepared by both acid and enzymic hydrolysis and were fractionated by Dakin's method. The whole proteins or the hydrolysates were fed on the basis of the nitrogen equivalent of 10 percent of protein fed as casein. The fractions were fed in amounts proportional to the respective yield of each.

The enzymic hydrolysate of deaminized casein was somewhat more protective than the deaminized casein from which it was prepared. Of the fractions, the diamino-dicarboxylic acid fraction of the enzymic hydrolysate afforded as much protection as the whole hydrolysate, while the monoamino and proline and peptide fractions showed no protection whatever. Blood-sugar determinations indicated that the protective action was exerted in the presence of the high blood sugar and not by a lowering of the blood sugar level.

4. *The Influence of Certain Diamino and Dicarboxylic Amino Acids upon the Cataractogenic Action of Galactose.* (H. S. Mitchell and G. M. Cook.) Following the lead suggested by the work just reported, some individual amino acids are being investigated. Glutamic acid, histidine, and arginine are all present in the protein hydrolysate fraction found to be most protective in the previous work. The amino acids are being fed incorporated in a low-protein galactose ration in order to observe any possible protective action. Results are not yet available.

5. *Time Factors in the Development of Galactose Cataract.* (G. M. Cook and H. S. Mitchell.) It has been observed in this and other laboratories that young rats are more susceptible to galactose injury than older rats. An experiment designed to investigate the question of this age factor is in progress. Rats from the same litter are started on experimental rations at fortnightly intervals. The ones started later require a longer time for lenticular injuries to become evident. The data are not yet complete.

The injury due to galactose seems to persist in rats after they have been transferred to rations containing none of this sugar. The blood sugar returns to normal within a few hours after the ration change is made. The apparent lag in the galactose injury must be due to slow diffusion from eye fluids. The extent of this lag is being investigated by discontinuing the galactose ration at four-day intervals on a series of rats from the same litter.

6. *The Influence of Different Salt Mixtures on the Utilization of Lactose.* (H. S. Mitchell and A. W. Wertz.) Preliminary evidence indicates that the amount and type of mineral elements in a ration may influence the rate of breakdown and absorption of lactose. Two commonly used salt mixtures seem to have slightly different effects. Experiments in progress are designed to study the effect of the type and amount of salt mixture on the growth, blood sugar, diarrhea, and lenticular change of rats fed a 60 percent lactose ration.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

W. W. Chenoweth in Charge

Cranberry Research. (C. R. Fellers and A. S. Levine.) Further study has shown that dextrose can be substituted for approximately one-third of the sucrose in canned cranberry sauce with no loss in quality. This finding should result in savings of about $45,000 on the canned cranberry sauce packed in Massachusetts alone.

Preliminary studies on cranberry seed oil show it to be a bland sweet oil containing approximately 200 U. S. P. units of vitamin A per gram as well as some antirachitic substance. Ursolic acid, a constituent of cranberry skins, was found to be entirely non-toxic to laboratory animals and men. Ursolic acid is a good emulsifying agent and may prove useful in certain food preparations.

Disintegration of cranberry waste (skins and seeds) in a hammer mill gives a finely divided mass which can be put back into the sauce to increase the yield. Since the pulper waste constitutes from 5 to 9 percent of the weight of the cranberries, recovery of this pectinous waste and its use in canned cranberry sauce should prove of marked economic interest. The percentage analysis of the disintegrated pulp showed: protein 11, fat and wax 20.3, nitrogen free extract 38.5, fiber 26.6, ash 2.5, and pectin (alcohol precipitate) 21.7.

Apple Products Including Apple Juice. (C. R. Fellers, A. S. Levine, W. A. Maclinn.) Except for the baking trade, canned apples have not been widely used by the consuming public. In a previous study (*Canning Age,* 20, (No. 2): 68-70, 82 and (No.4): 179-181, 1939), methods are described for packing canned baked or glazed apples. As a result of this study, several canners are now successfully packing this product.

Apple rings or sliced apples in syrup were extensively studied during the past year. In order to obtain good clearing and syrup penetration into the tissues, it was necessary to vacuumize the carefully cooked slices. The sugar hardens the fruit and a very acceptable apple dessert is thus obtained. A 40 percent sugar syrup consisting of 2 parts of sucrose to 1 of dextrose gave excellent results. The canned products retain their color and flavor very well during storage. The data are published in *Fruit Products Journal* 20 (No. 1) : 5-6, 25, 1940.

Bulletin 336, "Apple Cider and Cider Products" was reprinted, the supply having been entirely exhausted. Considerable time has been given to persons interested in making clarified apple juice, canned apple juice, and fermented cider of the sparkling type. Clear, sparkling bottled ciders containing both 3 and 7 percent alcohol have been prepared in the laboratory. Due to difficulty of control and clarification, it is not recommended that apple growers or small cider pressers attempt to produce cider containing 3 percent alcohol. A study was made of various clarification methods, including the use of pectin-dissolving enzymes and gelatin-tannin solutions. Deaeration of fresh apple juice was not found helpful in retaining the ascorbic acid or in improving flavor. There is some evidence that deaeration decreases can corrosion in canned apple juice.

Fruit Jellies. (C. R. Fellers, A. S. Levine, and F. B. Voit.) Efforts were concentrated on perfecting cider jellies and apple marmalades. Cider jelly was much used in colonial times and was prepared simply by boiling apple juice until it solidified into a tough rubbery mass at concentrations varying from 7 or 8 to 1. Jellies were prepared from cider in several ways such as by concentrating the clarified apple juice to one-half of its volume, adding sufficient sugar to make 50 percent soluble solids, and concentrating further to 68 or 70 percent solids, at which point a jelly is formed. For ciders from some apple varieties, the addition of pectin is necessary. As a suggested home recipe, boil 1 quart of fresh cider to a volume of 1 pint. Add 2 cups of sugar. Boil to a strong jelly test (221° F.). Depending upon the variety and condition of the apples, a little heat-extracted juice from either the fruit or pomace may be added as a source of pectin.

A good jelly of characteristic flavor can also be made from hard cider with the aid of added pectin and sugar. Very little alcohol remains in the finished product.

The base for cider marmalade was apple juice concentrated to 30 percent solids. Sugar was added to bring up the solids to 50 percent, and the temperature raised to 220° F. Thin slices of apple suspended in the jelly before it was poured into glasses cleared well and gave an attractive and tasty marmalade.

Nutritional Studies on Dog Foods. (John Bernotavicz.) A study has been in progress on the use of dried buttermilk powder as the major source of animal protein in a dry dog food. Exactly 50 percent of the animal protein fed was derived from this source. The chemical composition of buttermilk used was 33.72 percent protein, 6.75 percent fat, and 10.20 percent ash. Also present were 85 I. U. of vitamin B_1 per 100 grams and 1950 mgms. of riboflavin per 100 grams of buttermilk powder. The growth-promoting quality of the protein was excellent. The weekly gain in weight of the control dogs fed on a high-grade ration was 0.60 pounds as compared to 0.95 pounds for the animals on experiment. Both groups were fed 40 grams of food per kilo of body weight. Despite the high lactic-acid content of the powder, dogs raised from puppies showed no tendency towards diarrhea. The experimental animals showed a more glossy coat and more subcutaneous fat than the controls.

Work under way, at the present time, on dry dog biscuits shows that 10 percent of the total intake as casein prevents running fits in dogs. On the other hand, 5 percent of the total intake as canned dog food fails to prevent this condition.

Citrus By-products. (A. Sedky, C. R. Fellers, and W. H. Fitzpatrick.) A new method of making marmalade has been developed in which the orange peel is cooked separately. Retention of as much as 80 percent of the ascorbic acid as well as better flavor and color is made possible by use of this procedure. The time required for the preparation of marmalade may be greatly reduced if concentrated orange juice is used.

Experimental packs of both canned grapefruit sections and juice show that dextrose may successfully replace sucrose as a sweetening agent. In bottled grapefruit juice, the loss of ascorbic acid was proportional to the amount of oxygen present in the juice and container headspace. Thus, deaeration of fruit juices and vacuumization of the filled container are desirable in order to conserve the maximum amount of ascorbic acid in the bottled juice. Flavor is likewise improved.

Red Squill Research. (Cooperative with U. S. Fish and Wildlife Service.) (A. S. Levine and J. A. Lubitz.) Three papers are in press bringing up to date the publication of most of the red squill investigations. These include reports on the toxicity of squill to various animals, the factors affecting toxicity of red squill baits, and the relative values of several volatile oils and imitation food essences as rat lures.

Investigation has been completed to determine the optimum percentage of red squill powder to be used in baits. The more toxic the squill, the smaller the quantity required per bait. Thus, the more toxic squills are the most efficient and therefore more economical although the initial cost may be high at face value.

In a comparison of type of baits, the rats ate corn meal–squill baits in marked preference to poisoned baits made with meat or fish.

Preservative Values of Organic Acids. (A. S. Levine.) Investigations are being conducted to improve the preservation of soda fountain syrups and fruit juices. The present practice of adding citric acid and sodium benzoate is not entirely satisfactory. The substitution of acetic acid (vinegar) for part of the citric acid may lead to better keeping qualities without the need of sodium benzoate. Other organic acids are being studied and compared for their effect on the growth of yeast and molds.

The availability of sodium glycollate medium for the cultivation of anaerobes has made it possible to study the antiseptic effect of organic acids on anaerobic bacteria by the same technique previously employed and reported in similar studies with aerobic microorganisms. These results are needed to develop the theoretical considerations of this project.

Marine Products Research. (C. R. Fellers.) Efforts to can either blue, sand, or rock crabs have always failed. As a result of many years of study, a successful method for the canning of Atlantic crab meat has now been perfected. The method consists essentially in stabilizing the copper present in the hemocyanin of the crab's blood and flesh by means of a protective brine dip containing small amounts of aluminum salts at adjusted pH values.

The canned meat of the blue crab contains about 18 percent of high-quality protein; it is low in fat and high in ash. Particularly notable is the high content of essential minerals such as calcium, phosphorus, iron, copper, and iodine. The iodine content is from 400-500 parts per billion.

The meat contains moderate amounts of thiamin and riboflavin and a small amount of ascorbic acid.

The technique makes possible the establishment of an American crab-canning industry and introduces a new, attractive, tasty, and nutritious seafood to the American consumer. Four commercial canneries are already making use of this new canning procedure.

Research on crab meal for poultry feeding has been started in cooperation with the poultry department.

Carotene Studies. (C. R. Fellers and C. F. Dunker.) A comprehensive literature review and critique on the effect of canning, freezing, dehydration, and storage on the carotene (vitamin A) content of foods has been prepared for the Institute of Food Technologists. Collaborative studies with the U. S. Bureau of Agricultural Chemistry and Engineering on animal assays for vitamin A in frozen and canned peach products were undertaken. Excellent checks were obtained between the chemical methods for carotene and the rat biossay for vitamin A.

Glass Container Research. (C. R. Fellers, K. R. Newman, and W. H. Fitzpatrick.) Extensive experimental work on loss of quality of fruit juices packed in glass containers has been carried on.

As an antioxidant in bottled fruit juices l-ascorbic acid and d-gluco-ascorbic acid are more effective than oat flour, lecithin-dextrose mixture, or tyrosine butyl ester. Thus, any free oxygen present in fruit juice quickly reacts with ascorbic acid and accordingly reduces the vitamin C content of the juice. Heat greatly accelerates the oxygen-ascorbic acid reaction, although the final total loss of ascorbic acid in bottled juices is the same after one or two months' storage, regardless of temperature. However, other quality factors are better retained in fruit juices stored at cool temperatures.

Exposure of bottled juices to artificial light also accelerates the oxygen-ascorbic acid reaction; but again, the total ascorbic acid loss in light and in darkness, over a period of a few weeks, is approximately the same and is never greater than the theoretical loss due to chemical reaction of 100 percent of the oxygen with the necessary weight of ascorbic acid, that is, one molecule of O_2 combines with one molecule of ascorbic acid.

Research on Corn Distillers Dried Grains with Solubles. (C. R. Fellers, R. T. Parkhurst, and K. G. Shea.) This is a cooperative project with Poultry Department. Biological assays showed that this by-product is a very good source of riboflavin and vitamin B_1. While the biological value of the protein to rats is not high, when it was supplemented with casein, fish meal or meat scrap, growth was normal in every respect. For both White Leghorns and Rhode Island Red-Barred Rock hybrids, the distillers grains successfully replaced all the dried skim milk in the New England Conference starting mash at a marked saving in ration cost. Similarly, these grains could also replace about 50 percent of the fish meal plus meat scraps in the Conference Ration. The source of riboflavin and vitamin B_1 was found to be dried yeast cells and lactobacilli. It is estimated that yeast and bacteria comprise about 12 to 15 percent of the weight of the corn distillers dried grains with solubles.

Fruit Juice Concentration. (Lowell R. Tucker.) Fruit juices were concentrated by freezing and centrifuging. Machinery was constructed in cooperation with C. I. Gunness and a method developed for small scale operation at refrigeration plants. The qualities of the fresh juices were changed very little by freezing concentration and subsequent dilution. The degree of concentration that could be obtained without serious loss of soluble solids was often limited by the viscosity of the juices. This limitation was greatest with juices from cooked fruits because of their high viscosities. Highly viscous juices, such as cooked blueberry, currant, peach, and apple, could be concentrated to two-thirds to one-half volume. Less viscous juices, as elderberry, strawberry, and uncooked apple, could be concentrated to one-third to one-fifth volume. Cooked blueberry juice treated with pectinol had its viscosity so thoroughly reduced that it could be efficiently concentrated to 45 percent soluble solids, about one-fifth volume.

DEPARTMENT OF HORTICULTURE

R. A. Van Meter in Charge

Propagation of Hemlock. (Harold S. Tiffany, Waltham.) Tests on the propagation of Canadian hemlock (*Tsuga canadensis*) from cuttings were undertaken (1) to determine the effect of various constant temperatures and certain growth substances on hemlock cuttings, and (2) to secure uniform, own-root stock for fertilization experiments.

Cuttings were made up (Series I on Dec. 5-9, 1939; Series II on Jan. 30-Feb. 1, 1940) in lots of twelve for each of eighteen treatments, duplicated at temperatures of 60°, 65°, 70°, and 75° F. Temperatures were constant, maintained by electric cable and thermostat, with the exception of the 60° bench which fluctuated from 58° to 62° F. Treatments consisted of indoleacetic acid at 15, 25, and 50 mg. per 100 cc. for 16, 24 and 40 hours; indolebutyric acid in the form of Hormodin A (45 and 60 BTI units for 16, 24 and 40 hours); Hormodin Powder No. 3; and no treatment. The cuttings were placed in a medium of half sand and half peat in open benches under cheesecloth tents and kept fairly moist.

Except for slight indications (at 75° and 70° F. only) there were no rootings in check treatments. These initial rootings died before the end of sixteen weeks.

At nine weeks, a single treatment of the December cuttings (Hormodin A. 45 BTI units for 24 hours at 75° F.) showed outstandingly rapid rooting, with a 75 percent showing of fairly massive root systems. The 16-hour lot with this treatment fell to 37 percent, while the 40-hour treatment was 75 percent with less strong root systems. Since increased concentration of this treatment and lower temperature did not raise the percentage of rooting, there is a possibility that a still higher temperature with a lighter concentration would bring a higher percentage of rooting.

At sixteen weeks, 100 percent rooting resulted from thirteen treatments of cuttings in Series II. The most successful rooting (100 percent large root systems) resulted from indoleacetic acid 15 mg. per 100 cc. for 16 hours at 65° F. The percentage of rooting with this treatment fell to 90 at 70° F., and to 80 at 60° F., showing only a fair constancy for the treatment. With 24-hour immersion of the cuttings, however, this treatment was the most consistent, giving 100 percent rooting at 60°, 65°, and 70° F.

Indoleacetic acid, 25 mg. per 100 cc. for 24 hours, was also consistent, with rootings of 100 percent at 60°, 65°, and 70° F., but with somewhat smaller root systems.

Indolebutyric acid in the form of Hormodin A (60 BTI units for 40 hours) and of Hormodin Powder No. 3 gave 100 percent rooting at 70° F.

In general, the rooting of treated hemlock cuttings was definitely accelerated at higher temperatures, but the percentage of rooting was not as high as that obtained from the same treatment at lower temperatures. In opposition to this trend, a single treatment at 75° F. gave a good percentage of well-developed rooting as early as nine weeks.

Similar trials are planned for the coming season at like temperatures with more varied treatments. Three series of cuttings will be taken from December to late February at five-week intervals.

A series of identical treatments was made with cuttings of Carolina hemlock,, *Tsuga Caroliniana,* taken about December 12, 1939.

Only the strongest concentrations of indoleacetic acid solutions brought rootings of over 50 percent, requiring about five months. The response at 75° F. was negligible. At 70° F. a response of 20 to 40 percent was general from most treatments. The highest percentages of rooting came from the following treatments.

Percent of Rooting	*Treatment*
75	25 mg/100 cc Indoleacetic Acid 24 hrs. at 65° F.
58	25 mg/100 cc Indoleacetic Acid 40 hrs. at 65° F.
58	50 mg/100 cc Indoleacetic Acid 40 hrs. at 65° F.
67	50 mg/100 cc Indoleacetic Acid 40 hrs. at 60° F.

Propagation of Lilac. (Harold S. Tiffany, Waltham.) Terminal cuttings were taken on May 28, 1940, of the common lilac, *Syringa vulgaris* var. *Andenken an Ludwig Spaeth,* in lots of 75 for each treatment (except untreated lots with 15 cuttings): (1) Hormodin A solution 40 BTI units for 24 hours: (2) Hormodin Powder No. 3; (3) Formula "66"; and (4) untreated, at each of the constant temperatures, 75°, 70°, and 65° F. and an unheated bench. The medium consisted of two-thirds sand and one-third domestic peat. Cuttings were shaded by cheesecloth tents and lime on the greenhouse glass. Constant temperatures were maintained for the first five weeks only.

At the end of nine weeks the cuttings were potted. A temperature of 70° F. gave the highest percentage of rooting; Hormodin A, 99 percent; Formula "66", 96 percent; the untreated lot, 93 percent. Many of the untreated lot, however, were not sufficiently well rooted for potting. Constant temperature of 75° F. brought but one high percentage of rooting; 92 percent with Hormodin A. In general, rooting percentages mounted fairly constantly from lows with uncontrolled temperature through 70° F., and dropped decidedly at 75° F., because of burning.

All potted cuttings are in good condition with the exception of twenty-seven losses.

Factors Influencing the Hardiness of Evergreens. (Harold S. Tiffany, Waltham.) Plots of *Taxus baccata repandans* and *Taxus canadensis stricta,* set in the spring of 1939, received the first series of cultural treatments this season. Treatments were designed to produce widely varying types of growth for exposure to winter and artificially controlled temperatures.

A heavy application of nitrate of soda in early May produced early rapid growth. Two applications of stable manure and late cultivation produced late, poorly matured growth. Plants receiving cultivation without fertilizer, showed a somewhat greater average growth than those in sod and also exhibited well-filled textures, while those in sod were excessively straggly and weak in appearance.

Growth measurements were taken representing average maximum terminal growth of from five to twelve plants of each species. A study of the amount of winter injury by (1) leaf count and (2) percentages of dead terminal growth with (3) cross sections of the material under the microscope will furnish indications of the degree to which growth conditions resulting from the different treatments may be related to winterkilling.

Powdery Mildew on Garden Phlox. (Harold S. Tiffany, Waltham.) Control sprays were not applied until mildew (*Erysiphe cichoracearum*) was fairly plentiful on the plantings of *Phlox paniculata*. Materials tested included those used in 1939 and one additional. Again, Hammond's Copper Solution, leaving no residue, and Bordeaux Mixture, leaving a somewhat objectional residue, gave best results. The use of Bordeaux 1-1-50 gave just as good results as the 2-2-50 used in the test in 1939. In 1941 a spray program from early spring to blooming time will be tried.

DEPARTMENT OF OLERICULTURE

Grant B. Snyder in Charge

Variety Studies. (W. H. Lachman and G. B. Snyder.) These studies are conducted in cooperation with the Rhode Island and Connecticut Experiment Stations, to ascertain the influence of the various climatic and edaphic factors upon several strains and varieties of snap beans, celery, cabbage, tomatoes, peppers, and sweet corn. This concludes the third year of a five-year project so the data have not been summarized. Included in the vegetable plantings was Summer Pascal celery, which performed well and was of excellent quality. The Butternut pumpkin of the cushaw group yielded very well and was of high quality.

Shape Index Studies of Tomatoes. (W. H. Lachman.) This work has been continued with eight varieties of tomatoes, to determine the effect of climatic factors in modifying the shape of tomato fruits. Although data have been collected for four years, it is felt that more information is necessary before the results are summarized.

Tomato Breeding. (W. H. Lachman and G. B. Snyder.) The breeding work with tomatoes has been confined to the problem of incorporating the uniform ripening character into varieties which otherwise are very desirable. This has been relatively simple to accomplish because the uniform ripening character is evidently recessive in nature. Many lines have been obtained which are breeding pure for the uniform ripening character; but the self-pollination, which is necessary to obtain pure lines, has caused the selected progenies to segregate for other characters. The main problem now is the selection of lines which are stable for all characters. The oldest progenies are now in the F_5 generation and some of these appear to offer promise of worthwhile strains.

Sweet Corn Breeding. (W. H. Lachman.) Approximately 200 single plant lines have been selected from the 1600 original lines. The project was started four years ago so that many of the present lines are quite uniform in earliness, productivity, disease resistance, and quality. Many of the inbreds have exceptional vigor in relation to their earliness.

Approximately fifty of the best lines were crossed with an extremely early and productive inbred to study their general usefulness as parental material. Seed has been obtained from these crosses and will be tested in experimental plots during the coming year.

Hybrid Sweet Corn. (W. H. Lachman.) Seventy-one strains and varieties of yellow hybrid sweet corn were planted for trial during the past season. As in previous years many of these performed very well but were a little too late in maturing to qualify as excellent market garden varieties for Massachusetts. Of the varieties which were in the trials four are especially noteworthy: Spancross (C4 x C13) had only a medium-sized ear but was an extra early sort of good quality; Marcross (C6 x C13) was a few days later than Spancross, produced a large ear, and was very uniform in plant and ear characters; Carmelcross (P39 x C13) matured in the early midseason group of varieties, had a large ear, and was of excellent quality; Golden Cross Bantam was especially outstanding in the midseason class, had a large ear, was highly productive, and was of excellent quality. Ioana, which was a few days later than Golden Cross Bantam, produced well-formed ears of fair quality, filled to the tip.

Sources of Organic Matter for Greenhouse Tomatoes. (W. H. Lachman and G. B. Snyder.) Applications of straw, peat moss, cow manure, and horse manure have been made and incorporated in duplicate test plots in the greenhouse in an effort to obtain larger yields of greenhouse tomatoes as well as to ascertain the best source of organic matter. From preliminary observations it appears that peat moss may prove to be a valuable substitute for manure if sufficient commercial fertilizer is applied to compensate for the nutrients which are supplied in the manure. It is planned to repeat the tests several times before a summarized report is made.

The Effects of Mulching Tomatoes and Peppers. (W. H. Lachman and G. B. Snyder.) Various mulching materials were compared with clean cultivation for tomatoes and peppers. Straw, banana fiber, and horse manure were the materials used. Based on one season's results it appears that these mulching materials had little or no effect on the yield, percentage of cracking, or quality of fruit. Banana fiber was apparently quite effective in reducing the acidity of the soil, since these plots averaged approximately pH 7.2 while the pH of the soil from the other plots was about 5.7.

Cultural Practice Prior to Field Setting as Influencing Yield and Quality of Peppers. (W. H. Lachman.) Several methods of handling plants prior to field setting have been used to observe their effect on earliness, yield, and quality of the fruits produced. The Waltham Beauty strain of pepper has been used throughout the test.

Plants grown in clay pots with transplanting solution added produced a greater early yield than plants receiving any of the other treatments. Plants grown in paper pots suffered from nitrogen shortage, but applications of a weak solution of nitrate of soda appeared to correct the deficiency and these plants were among the highest yielders.

The weight of individual fruits was not greater on plots with high yields than on plots with low yields.

The addition of transplanting solutions in most cases increased the yield over the basic treatment. Transplanting solutions appeared to be quite effective in encouraging a quick replacement of roots and in stimulating early plant growth.

This project is being summarized in the Proceedings of the American Society for Horticultural Science.

Asparagus Investigations. (Robert E. Young, Waltham.)

Varietal Improvement. The yield records obtained for over 450 individual asparagus plants in five different lines show that the plants derived from high-yielding parents have greatly outyielded the commercial strain of seed in the trial. This is the first full cutting season for the plots. The two lines that had the greatest yield last year were the best producers again this year.

It was not possible to accurately forecast the relative rank of these lines by comparing last summer's stalk growth. Using the total summer growth for the four years, however, it was possible to forecast the rank in which the six lines would fall in respect to this season's yield. By examining the stalk count of last fall, it was also possible to pick out of all lines those individual plants which were the highest producers this year. This is a confirmation of former results obtained on the older plantings; counts of the stalk growth produced each summer show that, for the four years they have been growing, the plants produced the largest number of stalks the first year. Cutting the plants for two weeks the third year reduced the number of summer stalks remarkably. The full cutting this year did not affect the plants quite so adversely. Apparently they were better established. The variation in yield and stalk growth in any one of the five lines is not as great as that in the commercial seed.

When asparagus is compared with other vegetable crops, it can be readily seen that considerable progress must be made before a variety of asparagus can be established that would be comparable in uniformity of performance to other vegetable crops.

Depth of Planting and Height of Cutting. This project has been completed and the most pertinent results published. Results of practical value to asparagus growers are:

1. Deep planting reduced stand, mostly in the first and second years.
2. Deep plantings were slower to produce in the spring.
3. Asparagus crowns sought the level best suited for their needs. Many of the shallow-rooted plants went down and the deep-planted roots became more shallow. The average for all plots was 4 to 4½ inches from soil level to the top of crown.
4. Cutting the spears with 4 inches of green, which is the length of asparagus tips sold on some of our markets, did not give as high yields per plant as cutting the spears with 8 inches of green, the way most growers cut.
5. Allowing the spears to grow to 12 inches of green increased the yield

slightly but, of course, reduced the number of spears, and would probably bring the grower less returns. The important point in this connection is that cutting the spear with 12 inches of green did not exhaust the plant, as many growers expected. The yield relationships remained about the same throughout the experiment.

The results of this experiment would suggest the following recommendations:

1. Plant crowns 4 to 6 inches deep—shallower on heavier soil.
2. Cut spears with 7 to 8 inches of green for highest returns from the asparagus bed.

Vegetable Breeding for Improvement of Quality. (Robert E. Young, Waltham.)

Lettuce, New York Type. (In cooperation with United States Department of Agriculture.) The breeding work to develop a better adapted lettuce has progressed satisfactorily during the year. The new dark green selections found last year proved to be very desirable. They have dark green color, head well, are very crisp, and have a low percentage of tip burn. The one character that is not satisfactory at present is that most of the heads are not round but slightly flattened. Round-headed selections were made this year in an attempt to remedy this condition.

These selections are still segregating and will not be ready for release for a few more seasons. However, during the last trials, the best selections produced approximately three times as many marketable heads as did the best commercial strain. One further advantage is that most of the crop can be cut at one time.

The necessity of having a large number of selections from the better strains was further emphasized this year. Of the ten selections that were grown from last year's best strain two were of no value, two were only fair, and six showed varying degrees of heading.

Aster yellows, the disease that affected much of last year's crop generally in this section and destroyed 85 percent of the selected plants, was very mild this year. Not over 5 percent of the selections were affected. The reason for the variation in the severity of this disease has not been determined but it probably depends on the number of leafhoppers that live over winter.

Greenhouse Lettuce. The second generation of a cross between Bel-May, our regular greenhouse lettuce, and a dark green English lettuce was produced this year. The segregation of characters of this cross was very favorable to selecting the desired type. Twenty plants were saved and seed produced. It will require several generations to produce a uniform strain.

The supply of stock seed of Bel-May was replenished in the greenhouse under controlled conditions, with the expectation of eliminating the 3 or 4 percent of plants that are dwarf and mosaic-like although the exact nature of this trouble has not been determined.

Celery. Seed of the Summer Pascal celery was readily available and most of the local celery growers tried it. This celery has been generally accepted and is considered a big step forward in the production of a quality crop. Improvement in some of the characters is still needed, and toward this end seed from 20 individuals was grown and carefully noted. Three of this lot were considered superior and further selections were made. Selected plants were also saved to supply the immediate need for stock seed.

Attempts to speed the breeding program by sending plants to Puerto Rico to to be grown there failed because of heart-burn in the plants which became so severe they died.

Tomatoes. Growers of trellis and greenhouse tomatoes have used and appreciated the two strains of tomatoes (Waltham Forcing and Trellis No. 22) developed at the Field Station. Many have expressed a desire that we continue our work and attempt to remove the two or three undesirable characters they contain. In this connection, crosses were made in the greenhouse using Waltham Forcing, Trellis No. 22, and Early Trellis as one parent and Marglobe, Early Rutgers, and Michigan State Forcing as the other. These hybrids were grown last season in comparison with many strains of Comet of local seedsmen and, of course, the parents of the crosses. The hybrids showed pronounced hybrid vigor, producing more early fruit and a greater total yield. The hybrid vigor was so pronounced, and growers' comments about them so enthusiastic, that an attempt will be made to produce a small amount of hybrid seed for growers' trials. The large percentage of No. 1 fruits produced by our strains of tomatoes was also exhibited by the hybrids. Under intensive cultivation where the value of an acre of tomatoes is very high, the expenditure of $10 to $25 per acre for seed that will increase production from 15 to 25 percent would be within the reach of many of our growers.

Selections were made from the hybrid material to carry on the breeding program as originally started.

Rutabaga or Cape Turnip. The improvement program with Cape turnip was not greatly furthered during the year because the selected turnip plants failed to set seed in the greenhouse, and because what crop was planted outside was almost completely destroyed by cabbage maggot. Seed from other selected roots of the year before will be used for next year's crop.

Hutchinson Carrot. The improvement of the color and core of the Hutchinson carrot by hybridization is becoming more important as local consumers become more accustomed during the winter to carrots from other producing areas. The varieties used in other areas are not suited to our soil and are very susceptible to carrot blight.

The third generation of a cross between the Hutchinson and a Red Turkish carrot was grown this past fall and several lines were selected that were quite uniform and desirable. The biennial nature of carrots makes the breeding program slow.

Selection within the Hutchinson carrot to improve the strain has also been continued.

The supply of stock seed of the Field Station strain of Hutchinson carrot was replenished. The demand for this stock seed has been so great that it has been necessary to limit the quantity to 1½ pounds per seedsman.

Waltham Beauty Pepper. During the year a comparison was made between open-pollinated selections and the same plant self-pollinated in the greenhouse. While the characteristics of the population did not differ greatly and crossing in the field might not be visible, there was no detectable difference in the two lots of seed. Very few of the hybrids have shown the fruit setting ability of the Waltham Beauty and not shown the undesirable character of being hard to pick. About 25 lines were grown and many were discarded as undesirable.

Wyman Crosby Beet. The seed crop of this beet, which was to be sent to growers for trial, was almost a failure. As the seed becomes available, it will be put on trial.

Of the 12 self-pollinated lines grown this season, 2 were definitely outstanding as to internal color. Several were discarded because they were too light in color.

A change has been made in the technique of growing and selecting the best beet roots to better show up those specimens lacking in proper color. This different method will also speed up the program through the production of seed in the greenhouse.

Green Sprouting Broccoli. In the spring crop of broccoli 14 selfed, selected plants were compared to the 15 best commercial lines. There has been extreme variation in the time required for broccoli plants to produce a head, but comparing the two groups as a whole there was not much difference in their behavior. At the time of the first cutting, 33 percent of the plants in each group were harvested. In some lines in the selected group, as high as 85 percent of the plants were harvested. In the best commercial line, less than 50 percent of the plants were cut. Three weeks later, at the time of the last cutting, less than 5 percent of the plants in the best selection had not matured a head. This planting demonstrates the need for a better strain, and many selected plants were lifted from the field and self-pollinated.

Some of the same seed used for the spring crop was planted for fall. The best lines in the spring crop were not the best in the fall, indicating the need of two strains for the two seasons. Hybrids have been made between some of the best types and the early, poorly headed types obtained from Italy. Growers have contributed strains on which they have done work, and crosses have been made with these types to provide a redistribution of characters.

Greenhouse Cucumbers. During the year the work with cucumbers has been to collect all the desirable types possible from local growers and seedsmen which were not on hand from last year. These lines were grown in the field and self-pollinated to true up the lines before hybridization work. Mosaic was very severe in the field and only the early fruits were of value. A spring crop was grown in the greenhouse and some of the lines tested. From the vigor and yield of one hybrid under trial, it would seem that hybrid seed which growers could produce themselves would solve the problem of a better cucumber. The work of determining the best parents for such a cross will be continued in the greenhouse and field.

Rhubarb. In an attempt to find a better forcing rhubarb, a collection of varieties has been assembled and preliminary forcing studies made in one of the growers' forcing houses. Some of the strains had better color than Victoria, the variety generally used locally, but most of the strains did not have high yield. Keeping quality after harvest was studied and it was found that wrapping the rhubarb in moisture-proof cellulose sheets prevented deterioration. Further study on the variety problem is needed.

DEPARTMENT OF POMOLOGY

R. A. Van Meter in Charge

The past season was a reasonably favorable one for fruit crops. There was abundant rainfall in the early part of the season but the late summer and early fall were dry with much abnormally cool weather. The apple crop was good considering the heavy crop of 1939. There was some injury to the crop from freezing weather during the latter half of October. Peach buds survived the winter in adequate numbers and there was little cold injury to raspberry canes. Blueberry plants suffered more than usual.

The Influence of Various Clonal Rootstocks on Apple Varieties. (J. K. Shaw and L. Southwick.) Some of the stocks in the stool bed are dying, but Malling II, III, IV, XII, A, and C are still in fair to good condition. A new stock bed was set containing from 25 to 100 each of 21 clonal stocks. A part of the more valuable stocks were set upright for stooling and the rest set on an incline for laying down along the row. No rooted layers will be taken this year but the plants will be cut back in the spring, giving them time to gain vigor before being subjected to cutting.

Some of the cooperative clonal stock orchards are doing very well and others are failures, owing, in some cases, to unfavorable soil conditions and in others to poor management or neglect or perhaps bad luck. One new orchard of about 400 trees was set near Three Rivers.

The clonal stock orchard set in 1937 made excellent growth and a few trees bore good crops. Baldwin grew more on Malling I and IV than on Malling XV and Malling XVI, but Golden Delicious grew more on Malling XVI than on Malling V. Usually trees on semi-dwarfing stocks grow about as rapidly as those on standard stocks but begin to bear earlier, and this checks growth. Trees on very dwarfing stocks may grow less rapidly from the start and are likely to prove useful only in home gardens.

The McIntosh and Wealthy orchard set in 1928 became crowded and most of the Wealthy trees were pulled out, leaving a few scattered trees for pollination. Two plots running across the rows received a hay mulch to see how this affects the trees on different stocks, this treatment having given very favorable results in an adjacent orchard on seedling roots.

The larger orchard of 900 trees, set in 1939, made fair growth and the loss of trees from various orchard ills has thus far been very small. They are being grown under strip cultivation with mulch around the trees. All the Malling stocks in our stock collection, except VI and VII, are represented. The smaller orchard of 55 trees suffered from breakage of the tops and all trees were cut back and made a good whip growth.

A survey of the average growth as measured by trunk diameter fails to show any effect of the dwarfing stocks during the first two years of growth in the orchard. Trees on Malling III and IX have grown more than the same varieties on the "standard" Malling stocks in as many cases as they have grown less. The dwarfing effect will appear at fruiting, and possibly before, with some combinations.

Another interesting observation is that the yearling whips have increased in diameter at least as much as the trees that were two years old at setting, which supports the belief that one-year trees will reach bearing size as soon as two-year trees.

Tree Characters of Fruit Varieties. (J. K. Shaw, A. P. French, O. C. Roberts, and L. Southwick.) This was the twentieth year of nursery examination for trueness to name. A group of 18 nurseries has been visited annually for five years, one of them for all the 20 years. While the number of misnamed trees decreases with repeated examinations, few nurseries escape introducing a few misnamed trees. About the usual number of trees was certified by the Massachusetts Fruit Growers' Association.

The introduction of clonal stocks into the nurseries presents a new problem. Unless the stock is identified before cutting back after budding, it will be difficult or impossible ever to know certainly what stock is under the trees in the orchard. It would be entirely possible to examine the stocks before or after budding and the budded trees the next year and then certify the identity of both stock and scion variety when the trees are ready for sale. Something of this sort should be undertaken or great confusion and uncertainty will arise when and if trees on clonal rootstocks come into use.

The cherry variety nursery of about 45 varieties presented an opportunity for study, and descriptive notes and photographs were secured for publication. All the distinct varieties can be identified in the nursery row.

A pear nursery, including nearly all the varieties found in nurseries in this section of the country, was started. While most pear varieties are rather easily identified, there are a few that require closer study than can be given in nursery visits.

Some study was given to a collection of about 60 peach varieties, and most of them were rebudded for further observation directed toward the difficult problem of identifying peach varieties.

The Genetic Composition of Peaches. (J. S. Bailey and A. P. French.) During the year this project was redirected and rewritten to bring it more in line with work actually in progress. Data obtained during the year indicate that : (1) Genes F (free), M (melting), s (albino), and St (soft melting flesh) are linked in that order, and (2) M is 15 units from F, c 35 units from M, and St 5 units from c.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw.) No change was made in the soil treatment in this orchard, which has been under experiment for 20 years. Additional mulch to a depth of 1 to 2 inches was applied to plot 3 as in the previous two years. The trees are vigorous, with good foliage color and no signs of nitrogen deficiency, despite the fact that no nitrogenous fertilizer has been applied for 20 years. Attempts to harrow in the decaying mulch have not been too successful. Some mixing of the soil and hay has occurred and in this surface layer small rootlets from the apple trees are readily found. This fact is considered to be very significant and may explain in part the surprising apparent response of the trees in growth and fruiting.

Yields and growth of this orchard in 1940 have not yet been compiled, but yield was much lower than the record crop of 1939. As previously mentioned, two additional plots in a younger adjoining orchard were mulched for the first time this year. In all three of these plots, the mulch was applied to cultivated soils reasonably free from grass and weeds. Experience with them suggests that in starting a full mulching program, it may be wise to suppress grass and weeds by cultivation before the mulch is applied.

Determinations of loss on ignition as a measure of organic matter indicate that there is more organic matter in the soil of the sod plots than of the cultivated plots, especially in the 6 to 9 inch level except in cultivated plot 7. This plot is lower and wetter, and therefore the soil is less well aerated and the decomposition of organic matter proceeds more slowly. This determination will be repeated later to measure any changes that may appear.

Comparison of Cultivation and Heavy Mulching for Apples. (J. K. Shaw.) No additonal mulch was applied either to the block of mature Wealthy or to the old McIntosh block now planted to young Wagener and Rhode Island Greening trees. The decaying mulch is now 6 or 8 inches deep and should be sufficient for several years to come even though grasses, mostly quack grass, have grown up through the mulch. The trees continued to grow and produce well, and no injury from mice or fire has yet occurred. Networks of fine fibrous rootlets abound in the upper layer of the soil just below the decaying mulch. Both cultivated plots were fertilized with a nitrogen–potash mixture.

The Effects of Fertilizer Limitation on Fruit Plants. (J. K. Shaw.) The trees planted in 1931 have been removed and the experiment terminated for a time at least. The data await study and evaluation. The general result is that factors other than the fertilizer applications have greatly affected the growth of the trees.

Effect of Potash and Lime on Apple Trees. (J. K. Shaw.) This orchard was pulled out last winter and the experiment ended. The data accumulated in the past 20 years will be studied this winter. The area was seeded to rye in early fall. It is interesting to note that while the addition of phosphorus to nitrogen and potash did not improve the performance of the trees, the presence of phosphorus is the determining factor for good growth of the rye. One corner of the orchard had no fertilizer during the 20-year period, yet the rye grew almost, if not quite, as well as on the nitrogen-only plots. The addition of potash to nitrogen improved growth slightly; but on all plots which had received phosphorus with nitrogen, with potash, or in a complete fertilizer, growth of the rye was excellent.

Study of Varieties of Fruits. (J. K. Shaw and Staff.) The usual observations of the behavior of many of the newer varieties of fruits were made. A new orchard of peach and cherry varieties was set in early May, 1940, on contours on a moderately steep slope. It contains from two to five trees each of 67 new and old varieties.

Apple. Two red variants from the Pacific Northwest have fruited. The Seeando Red Rome this year was much inferior in size and color to Gallia. The latter is often sold as Red Rome but all trees under the name Red Rome may not be Gallia. Shotwell Delicious closely resembles Richared but is possibly a little darker in color.

Stamared is a sport of Stayman, dark red, obscurely striped and splashed. Otherwise, it is like Stayman and the nursery trees cannot be distinguished. It is promising for anyone who wants a highly colored Stayman.

Two varieties from the Prairie Northwest also have fruited. Sharon, of Iowa origin, resembles Duchess in color and has a firm juicy flesh but little flavor. Haralson has fruited for several years. It is a large round conic apple, lacking in quality. We have elsewhere stated it to be of Iowa origin, whereas it originated in Minnesota.

Four new varieties from Canada have recently begun to bear. Macross is a McIntosh seedling and the tree bears considerable resemblance to that variety. It is a roundish, dark red apple with obscure stripes and splashes. The flesh shows some reddish streaks. It is a little earlier in season than McIntosh, juicy, and of good quality. Hume is another McIntosh seedling of about the same season as Macross. It is dark red, splashed and striped, with a melting flesh of very good quality and a peculiar, rather agreeable flavor. Both of these are promising varieties and worth trying. Edgar is still another seedling of McIntosh crossed with Forest. It is later in season than McIntosh, which it resembles, though somewhat inferior to it in color. The flesh is juicy and good but not equal to McIntosh. Linda is a late winter apple, roundish, of an attractive red color and crisp, juicy flesh.

Cox Orange is a variety well known in England and is grown in Nova Scotia for export to English markets, where it is highly esteemed and brings a high price. The tree is somewhat lacking in vigor but bears fairly well. The apple is rather small, oblate conic, yellow partly covered with a bronze red, and not attractive in appearance. The flesh is subacid, crisp and melting, with a very good, spicy flavor. Perhaps it is not at its best here, but it is easy to see why it is valued by lovers of choice apples. It does not look promising for commercial use but might be desirable for the home garden.

Anoka is from South Dakota, is very hardy, and resembles Duchess. It is remarkable only for its dwarf growth and for coming into bearing very early.

Yates has been grown to see how a variety from the extreme southern apple region would behave here. It proves to be a small, smooth, oblate apple, with conspicuous dots and very poor flavor—an extreme case showing what happens when a variety is grown far from home.

Peach. New varieties of peaches are added to our variety orchards each year. Most of them prove unsuited to our conditions or not superior to established varieties of the same season of ripening. Yet such trials must be made if we are to find the occasional variety that is really an improvement. The following comments on a few varieties are based on one or more years observation in our orchards supplemented with what we have learned of their behavior elsewhere.

Ambergem is a good tough-fleshed clingstone canning peach two to three weeks earlier than Elberta. It is meeting with favor in eastern canning districts; but as we have no canning industry, it will not be planted here.

Candoka is a medium large, round, yellow-fleshed freestone peach of Elberta season or a little later. It is characterized by a red streak down the suture. The flesh is firm melting and of poor quality. It seems to have little or no value for us.

Hardee is a large, compressed, yellow-fleshed freestone peach, a little later than Elberta, unattractive, of poor quality, and of little or no value for us.

Polly resembles Champion closely, ripening a little ahead of it; white-fleshed, soft, freestone of not too good quality—not promising.

Sunglo is said to be an improved South Haven. With us it has shown little superiority, and considering that there are other excellent varieties of this season, it is doubtful whether it finds a place.

Sungold is a large, firm, freestone, yellow-fleshed peach of Elberta season; not very attractive and of only fair quality.

Fruit Bud Formation in the Strawberry. (R. A. Van Meter.) In 1939, twenty plots of 300 plants each, involving four treatments, were established to study the relation of time of mulch removal to the performance of fruit buds. An abnormally late, cold spring tended to eliminate the effects of differential treatments to such an extent that the trial is being repeated.

Twenty plots of 200 plants each were established in 1940. These were given differential treatments as follows:

1. Light mulch to be removed early.
2. Light mulch to be removed late.
3. Heavy mulch to be removed early.
4. Heavy mulch to be removed late.

It is expected that observations on these plants next spring will bring this phase of the study to an end.

Bud Mutations. (J. K. Shaw and W. H. Thies.) The collection of 20 bud selections of McIntosh budded last year served as a source of material for a new project elsewhere outlined. Trees of all 20 lots will be set for orchard observation.

Most of the bud sport selections top-grafted in 1930 have borne fruit. A solid red selection of McIntosh from our own orchards shows no signs of stripes or splashes, but all selections color about equally well. The selections from Wealthy differ very slightly if at all. Among the Baldwin selections, one which produced ill-shaped apples with a tendency to a five-lobed form maintains this character but is of no commercial value.

The most marked variation is among the Gravenstein selections. Scions from a "flat limbed strain", which did not show the malformation up to 1935, now show it, not only in the selected graft but on other branches in the same tree grafted with normal wood. It does not appear on two other top-worked Gravenstein trees in the same orchard. This suggests that this abnormality may be transmissible and possibly caused by a virus. One of the selections of Gravenstein for high color is rather exceptional and is being propagated for comparison with the Washington type now in cultivation. None of the other selections were much superior to the common striped type and some could not be distinguished from it. These observations are in harmony with the belief that Gravenstein more frequently shows bud mutations than other common varieties grown in Massachusetts.

Storage of Apples in Modified Atmospheres. (O. C. Roberts and L. Southwick in cooperation with Engineering Department.) McIntosh apples were stored in 40-quart milk cans from harvest time in 1939 until February 1940. It is probable that the cans were not gas tight, for the oxygen content in no can fell below 8 percent. No attempt was made to remove CO_2 which rose to a maximum of 16 percent with an average varying between about 5 percent and about 12 percent in different cans. McIntosh stored September 25 at 60°-65° F., in roughly 12 percent CO_2

and 10 percent oxygen, were ruined by scald; while others stored at 40° F. came through in excellent condition. Those stored October 11 in a similar atmosphere at 60°-70° F. rotted completely; while those stored at 40° F. were in excellent condition February 1.

Experiments are being continued with the cans tightly sealed by soldering a metal disc in the mouth of the can and metal tubes in the top and bottom for gas sampling and introducing gas for modifying the atmosphere in the can. Different levels of nitrogen, oxygen, and CO_2 will be maintained by controlled respiration, introduction of nitrogen gas, and "scrubbing" to remove CO_2. As the experiment is still in progress, no results can be reported at this time. The oxygen content decreased rapidly after the cans were sealed.

One of our small refrigerated storage rooms was gas-proofed, and 191 bushels of apples, mostly McIntosh but including other commercial varieties, put in the room, which was sealed on October 11. Brine coils on one side of the room made it impossible to fill the room as full as desirable, and the consumption of oxgyen through respiration has been less than hoped. The oxygen has fallen (December 16) only to around 13 percent, while the desired content is 2 percent. Evidently, gas-tight rooms must be filled at least to 80 percent capacity if the oxygen is to be reduced satisfactorily by respiration of the apples. The temperature is kept near 40° F. and apparatus devised for "scrubbing" the storage air to reduce the CO_2 content. The behavior of the apples in the cans, which are absolutely gas-tight and filled to capacity, shows that under these conditions the respiration of the fruit reduces oxygen and builds up CO_2 in a short time. Under the usual conditions of storage, it is impossible to fill a storage room completely full and difficult to make it completely gas-tight.

If storage of McIntosh in a modified atmosphere at higher temperatures than is usual in cold storage works out as investigations elsewhere promise, it will bring about a new situation in our apple industry.

Study of "Bud Sports" of the McIntosh Apple. (J. K. Shaw and L. Southwick.) This is a new project. It is natural to suppose that a type of McIntosh that is uniformly red all over with no sign of stripes and splashes is, in other respects, no different from other types of the variety. Yet it may be inferior in vigor, productiveness, or other respects and be undesirable for orchards in spite of its superior color. This project is planned to learn the truth about this. Six strains of McIntosh, believed to be of distinct origin, have been budded and will be planted in an orchard so planned as to make possible accurate measurements of any differences between the strains that may exist.

Tests of Spray Materials. (O. C. Roberts.) As in previous years, tests of several insecticides and fungicides were made in cooperation with the Departments of Entomology and Botany. A report of the season's work may be found in the report of the Department of Entomology.

Nutrition of the Highbush Blueberry, Especially in Relation to Soil Reaction. (J. S. Bailey.) On January 16, 1940, a series of sand cultures was set up to determine the deficiency symptoms of blueberry plants when various elements are left out of the nutrient solution. This experiment was concluded June 26, 1940. Kodachrome color slides were made of plants, showing the effects of omitting from the nutrient solution N, P, K, Ca, Mg, or B. One of the most striking results was the reaction of the plants to the acetate ion when it was substituted wholly or in part for the sulfate ion. The plants stopped growing and the leaves became very chlorotic. When the chloride ion was substituted for the acetate ion, the plants partly recovered.

In cooperation with Dr. Linus H. Jones of the Department of Botany, blueberry plants were grown in the soil temperature tanks at 55°, 60°, 65°, 70°, 75°, 80°, 85°, and 90° F. from February 19, 1940, to June 18, 1940. The following results were observed: (1) the plants at the two lower temperatures wilted during the first few days but later recovered; (2) total linear growth and height growth increased as soil temperature increased; (3) plants at 70° F. or higher tended to grow tall and upright; those below 70° F., shorter and more spreading. A report of this work will appear in the **Proceedings of the American Society for Horticultural Science for 1940.**

Blueberry Culture. (J. S. Bailey.) During the winter of 1939–40 there was considerable winter injury to the tops of blueberry bushes in the Experiment Station plantings. Although all varieties were injured to some extent, Rubel was injured much worse than any of the others. The cause of the trouble was probably a dry fall followed by cold, dry, north and northwest winds during the winter. The month of November was unusually dry. There were three weeks with no rain just before the ground froze. A frozen dry soil with cold, dry winds proved to be a bad combination for blueberries.

The Italian ryegrass, planted as a cover crop in 1939, was found to be a mixture of Italian and perennial ryegrass. It made a very good growth in most of the field and consequently furnished considerable organic matter, but it was rather difficult to subdue by cultivation the following spring. A further test of cover crops was started in the summer of 1940. Three special lots of seed were received from the Soil Conservation Service: (1) No. 3297 *Bromus arvensis,* field Brome grass; (2) No. 3197 *Lolium perenne,* perennial ryegrass; and (3) No. 2965 *Phleum pratense,* timothy. These were compared with oats and rye. Good stands of oats and rye were obtained, a fair stand of perennial ryegrass, a poor stand of field Brome, and practically no timothy.

During August, scion wood of the following blueberry selections was received from the U. S. D. A.: DN–76, AW–34, A–91, BM–22, T–72, R–86, L–25, AR–64, X–58, V–20, U–85, V–25, and AW–35. These were budded into Rubel plants in Row A, Plot C.

Plants of the newly named Pemberton variety yielded berries of exceptional size, very attractive appearance, and very good flavor. Berry size held up well throughout the season. The Concord variety bore an unusually large crop of large attractive berries this year.

The blueberry mite was observed for the first time in the College blueberries. It was not abundant and will probably never be a serious pest.

Premature Dropping of McIntosh Apples. (L. Southwick.) Work on this project was reported in Bulletin 372, published in May 1940. The best suggestions that could be made—such as increasing seed number by better pollination, lowering nitrogen in the tree thus decreasing vigor, thinning at the critical time, and spot picking—seemed either impractical or not effective enough. Unfortunate choice of soils favoring drop cannot be much alleviated though such soils should obviously be avoided in planting new orchards.

In 1939 the use of hormones was suggested and limited trials made that year gave some encouragement that they might have value. In 1940 several commercial preparations carrying these hormones came on the market, and the manufacturers supplied these materials which, with the pure hormone naphthalene acetic acid, were used in more extended tests. The usual concentration was 10 parts per million, but lower concentrations, and in one case a higher concentration, were used. Unsprayed check trees were used in all cases. Comparisons were made in nine orchard blocks on McIntosh, Baldwin, Wealthy, Duchess, and an unknown variety which always drops badly. Drops from each tree were gathered and counted, generally daily, and the numbers of apples picked were calculated. With Duchess and the unknown variety the spray was very effective, holding the apples until past the proper picking time while apples on the checks dropped heavily. With Wealthy and Baldwin the material was not very effective.

Most of the comparisons were on McIntosh, and effectiveness varied in the different tests. It appeared only on computation of the actual percentage of apples dropping. In some cases the effect was very small and in others it was marked, apparently preventing as much as 60 percent of the drop when picking was delayed. The effect appeared first about two or three days after the application and continued around ten to twelve days. About 15 to 35 gallons per tree, according to its size and crop, were applied. Concentrations of less than 10 p.p.m. seemed less effective, suggesting that until further investigation, it is unwise to apply at less than recommended strength.

It is doubtful whether many of the trials on McIntosh checked drop enough to be commercially profitable. It should be remembered that drop was much less in 1940 than usual. It is probable that in a year of normal or excessive drop the use of hormones would be more profitable.

The size of the crop on the trees is perhaps the most important factor in determining the profit from hormone spraying. With a heavy crop the number of bushels saved would be larger while the expense involved would be little more than with a light crop.

Our present feeling is that a McIntosh grower should have a supply of the material on hand and if warm moist weather prevails as harvest approaches, and especially if apples have not sized and colored sufficiently, he should apply it as soon as dropping becomes marked, even if he has to take some of his best pickers for the job. Our experience this year does not warrant any preference for any of the commercial preparations. All are presumed to carry practically the same content of hormone and differ only in the carrier, which may or may not affect the effectiveness of the hormone.

Miscellaneous Work

The Use of Peat in Planting Apple Trees. In May 1939, a small experiment was set up to test the effect of granulated peat on newly set trees. Twenty-six trees (mostly one-year whips) were planted in the usual manner. For an equal number of trees, each tree being paired with a check tree, the soil for planting was thoroughly mixed, 50-50, with twelve quarts of wet peat prior to setting each tree. Several varieties and rootstocks were represented. The peat had been used during one season for propagation purposes and was not strictly comparable to fresh peat. The paired trees were set between the trees in a newly planted orchard in four locations representing different degrees of soil depth, fertility, and moisture. Pruning was intentionally severe. All trees were cut back to 2–3 feet and the laterals removed.

Neither during the summer of 1939 nor during the summer of 1940 could any consistent differences in growth be detected in the field. Measured by trunk diameter, the check trees apparently have grown as well as the trees planted with peat moss. On three out of the four locations the treated trees grew slightly more but the differences are not significant.

Other work, notably at the New York Agricultural Experiment Station, has shown good results from the use of peat moss at planting time. Peat favored root growth and spur development. Since it is possible that trunk diameter may not accurately reflect total growth, it is planned to make further studies for any possible effects from the peat treatment. Then, too, there is the possibility that peat used in propagation frames for a season may not be as effective as "fresh" peat. There is no doubt that peat favors rooting under many circumstances, perhaps through improved aeration of the soil. Other investigation has shown that the best results are obtained in seasons with excessive soil moisture in the spring followed by drought conditions in midsummer.

It is suggested that as far as planting in Massachusetts is concerned, the natural soil and the site are the important factors. A poor orchard soil is extremely difficult to improve sufficiently for maximum tree performance. The use of peat in the planting operation does not seem necessary on a good soil, though it may prove helpful in some instances.

Soil Acidity in the Orchard. Repeated applications of sulfur sprays and dusts may cause an increase of soil acidity injurious to grass or cover crop and possibly to the trees. Samples of the top three inches of soil were taken from beneath a McIntosh tree growing in sod, which had been sprayed following the current schedules for over 20 years. Lime-sulfur was most used but wettable sulfurs and sulfur dusts have been increasingly used. Results were as follows:

Distance from trunk, feet	*pH Value*
4	4.50
9	4.80
15 (under branch tips)	5.08
20 (midway between trees)	5.60

The steady decrease of pH values, and therefore increase of acidity, towards the trunk is interesting. Probably sulfur sprays tend to run down and drip from the main branches; also when the trees were small, only the more central part of the area was subject to spray drip. The soil near the trunk is ten times as acid as that outside the branch tips and is too acid for many crops. While apple trees are quite tolerant of acid conditions, they may suffer at least indirectly from acid conditions such as these.

Another case of possible soil toxicity in a Sudbury orchard was called to our attention. A visit to the orchard showed that many trees were not vigorous and the grass and weeds under such trees were dead. The line of demarkation under the tips of the branches was sharp. The trees had been sprayed during this season with cryolite and it was estimated that about two pounds per tree had been applied. Cryolite contains, in addition to fluorine, considerable aluminum. Samples of the top soil were taken under four trees where the herbage was dead, together with check samples taken near by but between the trees where herbage growth was good, also similar samples taken beneath and outside a more vigorous tree with good grass beneath. Determinations of pH value and easily soluble aluminum were made by Professor Everson of the Department of Agronomy. The pH value varied from 3.98 to 4.62 and averaged 4.31; there were no consistent differences between the samples from the different locations. On the other hand, the soluble aluminum was rated as "very high" on all the samples taken where the herbage was dead and only "medium" or "high" in all cases where herbage was good. The pH value 4.50 is considered to be on the border line; below it there is danger and above it less danger of aluminum toxicity. It may be that the addition of aluminum from the spray was enough to increase the aluminum so that a toxic condition prevailed. Of course, a moderately heavy application of lime would correct such a condition.

DEPARTMENT OF POULTRY HUSBANDRY

R. T. Parkhurst in Charge

Broodiness in Poultry. (F. A. Hays.) Efforts are still being made to develop a genetically non-broody line of Rhode Island Reds by selective breeding using aged breeding stock. Birds for breeding are selected not only on their performance record but also on the broody behavior of their daughters.

A recent report on the inheritance of broodiness (Bul. 377) confirmed previous findings that degree of broodiness as measured by the number of broody periods is inherited. This study showed further that deferred broodiness was an important characteristic in dealing with the broody problem. Females exhibiting broody behavior first in the second or third laying year transmitted the broody instinct to about as many daughters as did females that expressed the broody instinct in their first year of laying. Rather definite evidence was presented to indicate the complete absence of sex-linked factors affecting broody behavior in Rhode Island Reds.

Statistical Study of Heredity in Rhode Island Reds. (F. A. Hays and Ruby Sanborn.) This project is devoted entirely to the preparation and analysis of experimental data for publication. During the year the following papers have been prepared: Inheritance of Broodiness in Rhode Island Reds, Station Bulletin 377; Color Markings in Rhode Island Red Chicks as Related to Sex and Adult Color, Jour. Agr. Res. July, 1940; Breeding Small Flocks of Domestic Fowl for High Fecundity, Poult. Sci. 19 (6), 1940; Transmitting Ability in Males of Genes for Egg Size, Poult. Sci. in press; Sex Ratio in Domestic Chickens, Am. Nat. in press; and Correlation in Egg Weight Between Mothers and Daughters, Jour. Hered. in press.

A Genetic Study of Rhode Island Red Color. (F. A. Hays.) Two lines of Rhode Island Reds are being developed in a study of the mode of inheritance of plumage color and the relation of plumage color to characters affecting egg production. One line is bred for early sexual maturity while the other is bred for late sexual maturity. This phase of the project is rather recent, but there is some evidence that the extremely dark shade of plumage demanded in exhibition birds is in part associated with the age at which sexual maturity is attained.

Rate of Feathering in Rhode Island Reds. (F. A. Hays.) The major objective of this experiment is to develop two lines of birds differing with respect to feather development on the back at eight weeks of age. A third line used as a check consists of stock bred for high fecundity with but limited consideration given to rate of chick feathering. Because of a striking sexual dimorphism in the sexes for rate of chick feathering, it is essentially impossible to classify female chicks at any age for rate of feathering on the basis of feather development over the back; therefore, attention has been directed largely to the males.

Line 1 has been sired exclusively through six generations by males with complete back feathering at eight weeks. Line 2 has been sired through the same period entirely by males having no back feathering at eight weeks. The check line was sired by varying proportions of rapid and slow-feathered males. The sixth generation gave the following percentages of rapid-feathering sons in 1940: line 1, 59.0; line 2, 2.2; and the check line, 28.4. Results to date indicate that rapid chick feathering in Rhode Island Reds depends on a series of recessive genes. A sex-linked gene for rapid feathering may be present, but many males having complete back covering may lack this gene. Up to the present time no important differences have been observed in the three lines with respect to characters affecting egg production.

The Effectiveness of Selective Breeding to Reduce Mortality in Rhode Island Reds. (F. A. Hays.) Cooperative project with Regional Poultry Research Laboratory, East Lansing, Michigan. The sixth generation of birds in this project completed their first laying year in the fall of 1940. In the low-mortality line 135 chicks were hatched in this sixth generation and their total mortality to six months of age was 6.6 percent. In the high-mortality line 153 chicks gave a mortality at six months of 10.46 percent. No losses from the paralysis complex were observed.

Forty-four pullets from the low line and forty-six from the high line were placed in the laying houses in September 1939. At the same time all of the brothers of these pullets were housed for the winter. There were 41 males in the low line and 47 males in the high line. Mortality records are complete for 11 months under these conditions. In the low line the mortality in pullets was 47.7 percent and in the high line 21.7 percent. The loss of males in the low line was 14.6 percent compared with 51.1 percent for the high line. For the total population, the losses were 31.8 percent in the low line and 36.6 percent in the high line.

Cannibalism was rather severe in both lines. If the cases of death apparently from cannibalism are omitted, the losses in the high and low lines were: Pullets, 20.4 percent and 13.0 percent; Males, 12.1 percent and 46.8 percent; Sexes combined, 16.4 percent and 30.1 percent. No appearances of diseases of the paralysis complex were observed in either line. The data appear to suggest that the males of the high-mortality line were decidedly less viable than the males of the low-mortality line. Why the losses in the females should fall in reverse order is not clear.

Genetic Laws Covering the Inheritance of High Fecundity in Domestic Fowl. (F. A. Hays and Ruby Sanborn.) Progress is observed in selective breeding of Rhode Island Reds for characters affecting high fecundity. Most of these characters are of rather complex genetic makeup. Early sexual maturity has been well established at a mean of about 190 days when birds are hatched in March and April. Intensity is still variable and the object is to attain a minimum of 3 eggs for winter clutch size. Winter pause has been reduced in duration, and the percentage of birds exhibiting pause has fallen as low as 27 percent. The percentage of broody birds and the degree of broodiness in broody birds have both gone to a low level. Persistency has improved so that the mean is not far below 365 days.

Beginning in 1929, comparisons have been made between the birds in this experiment and four strains from outside sources. From the standpoints of fecundity and of viability no outside strain has proved superior to our experimental strain. Crosses between the high fecundity line and these four strains did not produce superior birds.

Attention is also being given to fertility, hatchability, chick feathering, body weight, egg weight, plumage color, comb type, shank feathering, and inherited factors affecting mortality rate. Progress is being made without sacrificing desirable characters.

A Study of Fertility Cycles in Males. (F. A. Hays.) Records are being collected on the spermatogenesis of males of different ages through the fall, winter, and spring periods. Testicular tissue is being prepared for cytological study to develop some standard for comparing the reproductivity of different males. Particular attention is also being given to possible inherited factors affecting fertility in males. Preliminary data indicate notable differences in the histology of the testis as related to season.

Physiological Relationships Between Molting Behavior and Fecundity Characters. (F. A. Hays.) Bi-weekly records are still being made on the molting behavior of production-bred and exhibition-bred Rhode Island Red males and females. The third series of observations began July 25, 1940, and will be concluded December 26, 1940. The first breeding phase was begun during the spring of 1940 and data will be secured on the molting behavior of this first generation. The stocks available show wide variability in molting behavior, and several important relationships between molting behavior and fecundity are suggested.

Miscellaneous Studies. (F. A. Hays.) Several studies are being carried on under this heading. Rhode Island Reds are being studied for possible linkage relations between genes for shank feathering, genes for comb form, and genes for mottled ear lobe. Differences between Rhode Island Red plumage color and buff plumage color are being studied by hybridization. A method of separating sexes at hatching on the basis of down color is being studied in Rhode Island Reds. For auto-sexing, a type of gold barred bird is being developed.

Manganese Requirement of Rhode Island Reds to Prevent Perosis. (Marie S. Gutowska and Raymond T. Parkhurst.) To determine the threshold level of manganese necessary for the prevention of perosis in Rhode Island Reds, an experiment was conducted with four lots of chicks fed the standard perotic ration, supplemented with commercial ground calcites with and without manganese sulfate, so that the manganese levels in the rations were 20, 34, 46, and 60 parts per million. Perosis developed in the two lots of chicks receiving the rations with 20 and 34 parts per million of manganese. It was concluded that perosis in Rhode Island Reds can be secured by feeding the perotic ration when its manganese level is not higher than 34 parts per million. The commercial calcites proved to be satisfactory sources of manganese for chicks in the prevention of perosis.

Manganese Absorption in Fowls. (Marie S. Gutowska, with E. M. Parrott and F. S. Slesinski of the Department of Chemistry cooperating.) By the use of the isolated intestinal loop technique, the total amount of manganese absorbed from solutions of $MnSO_4.H_2O$ in 0.9 percent NaCl by Rhode Island Red cocks and hens was found to be proportional to the concentration of manganese in the loop. The percentage absorption of manganese from solutions containing 76, 40, and 10 p.p.m. averaged 35.8, 28.4, and 44 percent, respectively, in two hours. The amount of manganese absorbed per hour per kilogram of body weight in the fowl was relatively small compared with the amount of sugar or phosphorus reported absorbed by rats. Statistical analysis of results indicates that the difference in the absorption of manganese in males and females is not significant.

Manganese was still available for absorption when calcium ($Ca(NO_3)_2$) and phosphorus ($NaH_2PO_4.H_2O$) or (Na_2 glycerophosphate) were placed in the solution in the ratio of 3.91 to 1. An "in vitro" experiment, performed at 41° C., the normal body temperature of the fowl, using the same systems, indicated that practically all the manganese was still present in the solution after the precipitate which formed was filtered off.

A relatively small amount of manganese diffuses from the isolated intestinal loop in dead birds.

The Use of Corn Distillers Grains with Solubles in Poultry Rations. (Raymond T. Parkhurst and F. L. Dickens, with C. R. Fellers of the Department of Horticultural Manufactures cooperating.) Corn distillers dried grains with solubles satisfactorily replaced the dried skimmilk, all the dried skimmilk and fish meal, or all the fish meal and part of the meat scraps in the 1939–1941 New England College Conference laying ration. These substitutions had no effect on egg production, egg weight, body weight, egg quality, or feed efficiency, but lessened hatchability. When the corn distillers dried grains with solubles were used at a 40 percent level in the Conference growing ration, a desirable flushing effect was obtained in young growing birds affected with coccidiosis.

When "complete" laying rations were supplemented with mash, it made no marked difference in egg production, egg weight, body weight, egg quality, feed efficiency, or hatchability whether the mash was moistened with water or supplemented with corn distillers semi-solid grains. Excellent, but approximately the same, results were obtained in the finishing of Rhode Island Red cockerels when the 1939–1941 New England Conference growing ration was supplemented with intermediate cracked corn or equal parts of the corn and corn distillers semi-solid grains with solubles. The birds made an average gain of 3 pounds between 12 and 20 weeks of age.

Factors Affecting Growth, Pigmentation and Feathering in Broilers. (R. T. Parkhurst and Waldon T. Hastings.) Preliminary studies in batteries indicated that good growth, pigmentation, and feathering can be obtained when the 1939–1941 New England Conference starting mash is used as an all-mash broiler ration. The substitution of 1 percent of liver meal for 1 percent of meat scraps did not improve growth or shank color but gave much better feathering in the pullets. Satisfactory growth but lessened feed efficiency resulted when a partial substitution of fish meal for dried skimmilk was made. When the fish meal ration was supplemented with 5 percent kelp meal, there was no improvement in feathering, shank color, hemoglobin, erythrocyte count, or taste; and feed efficiency was less.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Control Service. (H. Van Roekel, K. L. Bullis, O. S. Flint, and M. K. Clarke.)

1. *Pullorum-Disease Eradication.* During the 1939-40 testing season there was a marked increase in the volume of testing over the previous year. Flocks were tested on 366 premises: 340 with chickens only, 6 with both chickens and turkeys, and 20 with turkeys only. A total of 689,377 tests was made: 680,663 for pullorum disease, 3,312 for fowl typhoid, and 5,479 for paratyphoid infection. The numbers of samples collected from chickens and fowl other than chickens were 676,611 and 12,776, respectively. Seventy-six reacting birds (66 chickens and 10 turkeys) were necropsied for 40 flock owners.

Testing service was rendered in 12 counties in which 673,222 chicken samples were tested for pullorum disease and only 0.51 percent were positive. No reactors were found among birds tested in 6 counties. All reactors were confined to 5 of the 17 breeds or varieties of fowl tested. Of the total chicken samples tested, 611,099 were from females (78,033 hens and 533,066 pullets) and 62,123 from males, among which 0.5 percent and 0.61 percent respectively were positive. The higher percentage of positive tests among males is attributed to the large number of male reactors in one large flock.

Tests were made of 346 chicken flocks representing 573,000 birds and 3,425 reactors were detected, 3,079 of which were found in 2 large flocks. "Breaks" were observed in 6 previously non-reacting flocks, in 4 of which the origin of infection could not be determined.

Pullorum-disease testing in turkeys has increased from 5,144 tests in 1938-39 to 12,771 in 1939-40. Three infected flocks were detected. Turkey growers are becoming more aware of the seriousness of this disease among turkeys.

Pullorum-disease eradication in Massachusetts is making satisfactory progress. During the past year 280 flocks were 100 percent tested with no reactors and represented 460,045 birds. With this volume of pullorum-free breeding stock, Massachusetts is in a positon to replace its poultry population with pullorum-disease-free chicks.

During the past year this department has continued to cooperate with the Massachusetts Department of Agriculture by making available testing results which are used for official recognition and classification of pullorum-tested flocks.

2. *Diagnostic Service.* Personal delivery of specimens accounted for 405 of the 607 consignments including 3,026 specimens which are classified as

follows: 2,545 chickens; 307 turkeys; 55 pheasants; 29 canine feces; 15 ducks; 14 rabbits; 10 pigeons; 9 quail; 6 each of canary and mink; 5 each of canine, sheep, and swine; 3 each of bovine semen and bovine skin scrapings; 2 each of bovine feces, canine urine, and feline; 1 each of insects, ruffed grouse, and swine abscess.

The incidence of the more common and important disease conditions observed in chicks during the past five years is as follows:

	1935-36	1936-37	1937-38	1938-39	1939-40	Total
Avian tuberculosis		1	1	3	1	6
Coccidiosis	59	35	64	97	82	337
Enterohepatitis	6	2	7	6	7	28
Epidemic tremor	26	8	35	22	19	110
Fowl cholera	3	11	3	16	12	45
Fowl coryza		5	2	1		8
Fowl paralysis	39	37	45	77	47	245
Fowl pox	4	8	30	21	7	70
Fowl typhoid		4	2	11	4	21
Infectious bronchitis	19	40	31	48	57	195
Infectious laryngotracheitis	8	12	9	19	14	62
Internal parasites	21	23	21	41	26	132
Kidney disorders	25	17	15	37	21	115
Leukemia	11	7	3	6	3	30
Nutritional encephalomalacia	10	1	7	13	8	39
Paratyphoid	1	1	2	3	1	8
Perosis	10	4	2	4	3	23
Pullorum disease	44	39	46	49	32	210
Reproductive disorders	12	22	14	20	21	89
Rickets	9	8	6	19	19	61
Tumors	39	53	46	79	53	270
Gizzard erosions		1	15	14	15	45
Unknown disease	15	9	11	24	26	85
Unknown pullet disease	2	6	6	11	9	34

The 307 turkey specimens were received in 57 consignments. Coccidiosis 9, enterohepatitis 12, paratyphoid 14, and rickets 8, accounted for 51.8 percent of the diagnoses. Pullorum disease was noted in only one lot of poults and these were shipped in from out-of-state. That pullorum disease was present in some breeding flocks is indicated, however, by the isolation of *S. pullorum* from 6 of the 10 birds examined bacteriologically following the application of the agglutination test to 3 turkey flocks. A potentially important observation was made when *S. typhi-murium* was isolated from breeding birds over one year of age. Excessive mortality was reported in this flock during the breeding season. Poults from this flock were affected with paratyphoid infection. Fowl typhoid and fowl cholera were not identified in turkeys during the year. Swine erysipelas was identified in one case and ulcerative enteritis in 2 cases. A condition which has been reported to resemble perosis was observed in 2 flocks at about 16 weeks of age. Approximately 10 percent of the birds in one flock were affected.

Among pheasants a cecal infestation with a capillaria species was observed for the first time in this laboratory. We are indebted to members of the Zoological Division, Bureau of Animal Industry, United States

Department of Agriculture, who identified this parasite as *Capillaria caudinflata.*

3. *Flock Mortality Studies.* During the year, 277 morbid and dead birds from the Experimental Poultry Farm were necropsied. Unusual outbreaks of disease were not noted. The birds were hatched during the past five years. Among the birds received from those hatched in the spring of 1939, the largest number of males, 78.4 percent, was submitted from January to May 1940, inclusive; the largest number of females, 73.7 percent, from April to July, inclusive. In this group of birds cannibalism 17, and kidney disorders 14, accounted for 56.4 percent of the diagnoses among the males; and reproductive disorders 74, cannibalism 61, and kidney disorders 20, amounted to 76.3 percent of the diagnoses among the females.

4. *Avian Pox in Ruffed Grouse.* During October 1940, a grouse head was submitted by a person who had shot the bird during the hunting season. It was reported that the bird's flight was abnormal and that excrescences were observed on the eyelids and on the skin posterior to the upper beak. Laboratory examination revealed a suspicion of fowl pox infection. A saline emulsion prepared from the affected tissues and applied to scarified combs and wattles of susceptible chickens produced typical lesions of fowl pox within 8 days after inoculation. The inoculation of pox lesion material from the chickens into pheasants produced evidence of pox infection within 8 days. While pox has been reported in grouse previously by other investigators, this case is of interest to poultrymen and those concerned in upland game bird propagation. Furthermore, this case tends to substantiate the possible reservoir and hosts which may serve as a source of fowl pox infection to poultry, especially on range where direct contact between chickens, grouse, and pheasants is possible.

5. *Salmonella Types Isolated.* Salmonellosis is a disease entity which may occur in a variety of hosts and may be due to many species of organisms in the Salmonella group. The commonly designated paratyphoid organisms in the Salmonella group may cause severe losses. These paratyphoid infections express themselves most frequently among turkey poults, although their incidence among chickens is not to be underestimated.

During the past seven years, 68 strains were typed that had been isolated from specimens received at the laboratory. We are greatly indebted to Dr. Philip Edwards, Department of Animal Pathology, University of Kentucky, Lexington, Kentucky, who identified these strains as to type. The 68 cultures were isolated from the following types of specimens: Mature chickens 4; chicks 16; mature turkeys 3; poults 35; turkey egg 1; mature pigeons 3; and pheasant chicks, ducklings, canary, squab, wild mouse, and commercial rat virus each once. The incidence of the types is as follows: *S. typhi-murium* 47; *S. anatum* 5; *S. bareilly* 3; *S. kentucky* 2; *S. oranienburg* 2; *S. enteritidis* (var. *danysz* and var. *jena*); *S. newport; S. derby; S. newington; S. new brunswick; S. minnesota; S. meleagridis*; and *S. thompson* each once.

During the past year, 17 strains were isolated and identified and all but one (*S. oranienburg*) were typed as *S. typhi-murium.* All of the 17 strains except one were isolated from mature and young turkeys and one turkey egg. Investigational work of a control nature is in progress.

6. *Viability of S. pullorum.* Studies to determine how long *S. pullorum* will remain alive in a dry piece of cloth stored at room temperature showed the organism to be alive after 7 years, 8 months, and 4 days. The last of the cloth prepared for this investigation was examined at the end of a period of 8 years, 3 months, and 8 days and no viable organisms were recovered.

7. *Transmission of Pullorum Disease by Cohabitation.* An attempt to transmit pullorum disease to non-reacting females gave negative results when non-reacting females and reacting males were confined in the same pen over a period of 9 months.

8. *Avian Encephalomyelitis.* Investigations during the past year have further substantiated that mature pheasants appear refractory to the infective agent when inoculated intracerebrally. Pheasant chicks inoculated intracerebrally failed to show definite symptoms, but brain suspensions prepared from these pheasants 76 days after the inoculation revealed that the infective agent was still present and capable of producing the disease in chicks. The virus was not demonstrable in the spleen after this period. Cohabitation of inoculated chicks with susceptible chicks produced positive transmission to the latter. The degree of spread however was slight. Fresh citrated blood obtained from affected chicks was capable of producing the disease in chicks when inoculated intracerebrally, intraperitoneally, and subcutaneously. This was likewise true of liver and spleen tissues inoculated by the intracerebral route. Chicks inoculated by intraperitoneal and subcutaneous routes readily contracted the disease. A group of 309 chicks (consisting of 2 different hatches) were hatched from eggs obtained from a commercial breeding flock whose progeny revealed one outbreak of the disease. The chicks were hatched and reared under control conditions. No evidence of the disease was noted. The infective agent used in some of the above-mentioned experiments is now in its 104th serial passage. Through repeated passage in chicks, the virus acquired a shorter incubation period, a shorter disease course, and a mortality rate of 100 percent.

9. *Farm Department Brucellosis Control and Eradication.* The laboratory cooperated in this work by testing 328 bovine blood samples with the standard tube agglutination method.

Studies of Neoplastic and Neoplastic-like Diseases. (Carl Olson, Jr.) The transmissible lymphoid tumor of the chicken (described previously in Annual Reports for Years Ending November 30, 1938 and 1939) has now been carried through more than 60 serial passages in experimental chickens. The results for the first 30 passages in whch birds received implants of the tumor either in subcutaneous or muscular tissue are summarized in the following table:

Number Inoculated	*Negative*	*Growth*
443	143	300
	(32.3%)	(67.7%)

Regression of the growth occurred in 133 of the 300 chickens after it had reached a maximum state of development on an average of 13.6 days after inoculation. No pertinent pathology was observed in these birds at necropsy. The tumor had remained localized and actively growing in 116 of the chickens at the end of their experimental life, which averaged about 23 days. In several instances the tumor had attained a size of more than 20 percent of the body weight of the host.

Metastasis of the tumor was observed in 51 cases. Metastatic foci of the tumor were found in most of the visceral organs, although they were more commonly noted in the heart, proventriculus, and adrenal glands. In 21 of the cases only a single visceral organ was affected with tumor. One case of diffuse metastasis in the liver, spleen, and bone marrow was noted in the twenty-sixth serial passage of the tumor. Such cases have been encountered frequently in chickens inoculated with material after the forty-fifth passage of the tumor, and the birds die from 9 to 15 days after inoculation. Such a reaction represents a new character of the tumor that has developed due to serial passage.

Fowl paralysis developed in some birds after implants of the tumor (about 3 percent of those inoculated in the first 30 serial passages). There were eight cases (about 5 percent) of fowl paralysis among 151 uninoculated control chickens. The average age when the first symptoms were noted was approximately 72 days in the case of inoculated and 67 days in the case of uninoculated chickens. Therefore, there seems to be no significant association of fowl paralysis with the transmissible lymphoid neoplasm.

Progress has been made on the study and classification of more than 300 cases of spontaneous neoplastic disease in chickens derived from various sources.

Studies of the antigenic composition of blood cells of chickens, discussed in a previous Annual Report (for Year Ending November 30, 1939) have been continued. The results to date may be briefly summarized as follows:

The mating of chickens whose blood cell types were Class I produced progeny with blood cells of the same class. The mating of chickens whose blood cells were of Class II produced progeny with blood cells of the same class. The mating of chickens whose blood cells were Class III produced progeny with blood cells of Classes I, II, and III in the ratio of approximately 1, 1, and 2, respectively. The mating of chickens in which one sex had Class I blood cells and the other sex had Class II blood cells produced progeny with Class III blood cells. These results lead to the tentative conclusion that the genotype of Class I cells is a combination of two dominant genes (AA); Class II cells, of two recessive genes (aa); and Class III cells, of dominant and recessive genes (Aa).

WALTHAM FIELD STATION

(Waltham, Mass.)

Ray M. Koon, in Charge.

The members of the research staff of the Waltham Field Station are assigned to the unit by the Departments of Botany, Entomology, Floriculture, Horticulture, and Vegetable Gardening. Reports of these departments give results of investigations conducted at this station.

Evaluation Gardens. The collection of hardy perennials numbering about 2000 species and varieties has proved to be of definite value to commercial nurserymen and the general public.

Promising new perennials received in the spring of 1940, although not yet tested over winter, include:

Astilbe Fanal (*A. arendsi* var. *Fanal*) bears well-shaped spikes of a clear wine red; a new color in this genus.

Phlox paniculata var. *Eva Foerster,* a dwarf form and vigorous grower, is deserving of particular notice. Its blossoms carry a fine strong pink tone after the salmon tinge of the newly opened florets has disappeared.

Heliopsis patula (Le Moine strain) repeats the fine characteristics of *H. scabra* var. *incomparabilis* with its sturdy, yellow, 3-inch, semi-double, late summer blooms. The plants were too young to indicate whether or not this variety extends the bloom season beyond that of *H. scabra* var. *incomparabilis.*

Oenothera glauca var. *Illumination* and *O. fruticosa* var *Yellow River* definitely promise extension of the blooming season for this species.

Clematis: A varietal form of the fragrant tube Clematis (*C. heracleaefolia* var. *davidiana*), available this year under the name Azurea, gave a prolific bloom and greater fragrance than other varietal forms.

Peonies: Among the single Japanese peonies (whose blossoms, being less heavy than double forms, recover from heavy rainstorms rapidly), the following are outstanding: Ama-no-sode, Currant Red, Isani Gidui, Dog Rose, Edward VII, and Tokio.

In order to acquaint the public with the best of the azaleas, plants of the following species and varieties were set out in the spring: *R. arborescens, calendulaceum, canescens, dauricum* var. *mucronulatum, japonicum, nudiflorum, obtusum* var. *kaempferi, roseum, schlippenbachi, yedoense* var. *pouklanense, vaseyi,* and *viscosum.* This list, approved by growers of eastern Massachusetts, represents azaleas most successfully grown in this region.

Field Day. The twenty-second annual Field Day on August 7, 1940, attracted over 1300, the largest number of visitors yet recorded. This attendance, in spite of threatening weather early in the day, shows the keen interest of the growers in the work at the Field Station. Eight entries in the new Summer Pascal celery contest demonstrated how widely this variety has been planted in this, its first year in commercial production. Because of the increased interest in machinery, it was necessary to enlarge the area devoted to exhibits.

Soil Testing Service. To most individuals soil tests are of value only when an interpretation of the findings can be made by some qualified person. Such an interpretation must invariably be accompanied by a recommendation for treatment. A total of 6050 samples was tested in 1940, compared with 2704 in 1937.

PUBLICATIONS

Bulletins

336 Apple Cider and Cider Products. By J. A. Clague and C. R. Fellers. 36 pp. July 1940. (A reprint of a bulletin issued first in November 1936.)

Greater care in the application of approved known methods in the production and preservation of apple cider and cider products should make for an enlarged demand for these popular by-products of the fruit industry. This bulletin gives the results of investigations in this field.

369 Annual Report for the Fiscal Year Ending November 30, 1939. 104 pp. February 1940.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

370 Transmissible Fowl Leukosis. A Review of the Literature. By Carl Olson, Jr. 48 pp. April 1940.

There is considerable uncertainty as to the relationship between the various diseases grouped under the term "fowl leukoses," due partly to the varying results obtained by different investigators and also to the indiscriminate use of terms. This review of the literature was prepared in the hope that it might help to clear up this confusion and thus lead to a better understanding of these diseases—a necessary preliminary to the development of control measures.

371 Cranberry Growing in Massachusetts. By Henry J. Franklin 44 pp. June 1940.

Directions for growing cranberries, from the selection and preparation of the land to the harvesting and marketing of the berries, with photographs illustrating all important points.

372 The McIntosh Drop. By Lawrence Southwick. 19 pp. May 1940.

Among the factors considered, methods of culture which produced the most vigorous growth and heaviest yields also had a tendency to increase drop. Apples with many seeds tended to hang longer than those with fewer seeds. Experiments with several chemical sprays were successful in delaying or preventing drop, but further study is needed to determine whether this method is practical for general orchard use.

373 Foods and Public Health. By James E. Fuller. 16 pp. May 1940.

The aim of this bulletin is to present fundamental information about food-borne diseases in a manner comprehensive yet simple. Only those food-borne diseases are discussed that are important in the every-day life of the average community. Diseases that occur only rarely or not at all in our country are not included.

374 Minerals in Nutrition. 40 pp. August 1940.

Several departments in the Experiment Station have been cooperating in studies designed to add to our knowledge of minerals in foods, particularly the relation of minerals to certain disabling diseases such as arthritis and hardening of the arteries. The following papers are included:

I. Total nutrients and minerals in human and cattle foods.
II. The absorption by food plants of certain chemical elements important in human physiology and nutrition.
III. Possible relationship of Vitamin C and arthritis.
IV. The effect of kelp and mineral supplements on atherosclerosis in rabbits induced by feeding cholesterol.
V. Effect of added iodine on the enzymes of milk and on other enzymes.
VI. Added iodine in milk and fecal bacteria.
VII. Iodine and bacterial counts in milk.

375 Biological Control of Mealybugs in Greenhouses. By W. D. Whitcomb. 22 pp. July 1940.

Laboratory studies demonstrated the possibility of biological control of mealybugs by the use of the imported ladybird beetle, *Cryptolaemus montrouzieri,* Muls., and indicated some of the conditions necessary for success. Tests were then made in greenhouses to determine whether and under what conditions this method of control is practical in commercial practice.

376 The Culture and Forcing of Easter Lilies. By Harold E. White. 20 pp. August 1940.

The culture of Easter lilies for potted plants and cut flowers is an important source of income to Massachusetts florists. The cultural conditions necessary for success with this crop are described and discussed, with special reference to the effect of controlled rooting temperatures on the growth of the lilies.

377 Inheritance of Broodiness in Rhode Island Reds. By F. A. Hays. 11 pp. October 1940.

Breeding tests extending over ten years have led to the following conclusions. Broodiness as measured by the number of broody periods in the first laying year is inherited. Broodiness depends in inheritance on two complementary dominant genes, neither of which appears to be sex-linked. Deferred broodiness greatly retards progress in breeding to eliminate the broody trait, and the complete elimination of broodiness appears to be very unlikely.

Control Bulletins

103 Twentieth Annual Report on Eradication of Pullorum Disease in Massachusetts. By the Poultry Disease Control Laboratory. 13 pp. June 1940.

104 Inspection of Commercial Feedstuffs. By Philip H. Smith. 72 pp. October 1940.

105 Inspection of Commercial Fertilizers. By Philip H. Smith and J. W. Kuzmeski. 49 pp. October 1940.

106 Inspection of Agricultural Lime Products. By Philip H. Smith and J. W. Kuzmeski. 11 pp. October 1940.

107 Seed Inspection. By F. A. McLaughlin. 104 pp. November 1940.

Meteorological Bulletins

613-624, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. By C. I. Gunness. 4 pp. each.

Reports of Investigations in Journals

Numbered Contributions

335 Vitamin B_1 and vitamin B_2 (G) content of vegetables as influenced by quick-freezing and canning. By C. R. Fellers, W. B. Esselen, Jr., and G. A. Fitzgerald. Food Res. 5 (5):495-502. 1940.

340 Onion juice and bacterial growth. By James E. Fuller and Ernest E. Higgins. Food Res. 5 (5):503-507. 1940.

342 Coliform bacteria and streptococci in swimming pool water. By Ralph L. France and James E. Fuller. Amer. Jour. Pub. Health 30 (9):1059-1062. 1940.

343 Observations on the development of certain cell-wall constituents of forage plants. By Emmett Bennett. Plant Physiol. 15:327-334. 1940.

345 Effect of benzoated brine dips on keeping quality of fish fillets. By C. R. Fellers and E. W. Harvey. Food Res. 5 (1):1-12. 1940.

351 Pectins and the texture of cooked potatoes. By Monroe E. Freeman and W. S. Ritchie. Food Res. 5(2):167-175. 1940.

352 Action of acetic acid on food spoilage microorganisms. By A. S. Levine and C. R. Fellers. Jour. Bact. 39 (5):499-514. 1940.

353 Canned Atlantic crab meat—A new American food. By Carl R. Fellers and Sterling G. Harris. Indus. and Engin. Chem. 32:592. 1940.

354 Pullorum disease control and eradication. By Henry Van Roekel. Vet. Med. 35 (1): 1940.

356 The grape plume moth. By W. D. Whitcomb and W. E. Tomlinson, Jr. Jour. Econ. Ent. 33 (2):372-374. 1940.

357 Report on Zinc. By E. B. Holland and W. S. Ritchie. Jour. Assoc. Off. Agr. Chem. 23 (2):302-303. 1940.

358 Injury to trees from sulfur dioxide fumes of electric refrigerators. By Malcolm A. McKenzie and Linus H. Jones. Science 91 (2358):239-240. 1940.

359 Spur nitrogen and pre-harvest McIntosh drop. By Lawrence Southwick. Amer. Soc. Hort. Sci. Proc. 37 (1939):435-437. 1940.

360 The depth of planting asparagus and its effect on stand, yield and position of the crown. By Robert E. Young. Amer. Soc. Hort. Sci. Proc. 37 (1939):783-784. 1940.

361 Inhibiting effect of acetic acid upon microorganisms in the presence of sodium chloride and sucrose. By A. S. Levine and C. R. Fellers. Jour. Bact. 40(2):255-269. 1940.

362 Effect of exercise on growth and cataract development of rats fed galactose. By Helen S. Mitchell and Gladys M. Cook. Proc. Soc. Expt. Biol. and Med. 43:85-86. 1940.

363 Phomopsis gardeniae in relation to gardenia culture. By Malcolm A. McKenzie, Linus H. Jones, and Constantine J. Gilgut. The Plant Disease Reporter 24 (3):58-62. 1940. (Mimeographed)

364 Breeding small flocks of domestic fowl for high fecundity. By F. A. Hays. Poultry Sci. 19 (6):380-384. 1940.

366 Syrup of cranberry, a new pharmaceutical vehicle. By J. A. Lubitz, C. R. Fellers, and J. A. Clague. Jour. Amer. Pharm. Assoc., Sci. Ed., 29 (7):323-325. 1940.

367 Study practical gardenia canker control as disease increases. By M. A. McKenzie, L. H. Jones, and C. J. Gilgut. The Florists' Review, March 28, 1940.

368 Color markings in Rhode Island Red chicks. By F. A. Hays. Jour. Agr. Res. 61 (1):69-74. 1940.

372 Propagation of white pine by cuttings. By William L. Doran, Robert P. Holdsworth, Arnold D. Rhodes. Jour. Forestry 38 (10):817. 1940.

373 Canned dessert apples. By A. A. McCormack, C. R. Fellers, and W. A. Maclinn. Fruit Prod. Jour. 20 (1):5-6, 25. 1940.

374 Soil as rooting medium for cuttings. By William L. Doran. Amer. Nurseryman 72 (5):7-8. 1940.

378 Grass silage on Massachusetts dairy farms. By Charles R. Creek. 17 pages, mimeographed. August 1940.

382 Vitamin C in packaged foods purchased in retail markets. By K. R. Newman and C. R. Fellers. Jour. Amer. Dietet. Assoc. 16 (7):695-696. 1940.

Unnumbered Contributions

Put the minerals on the land—not in the manger. By J. G. Archibald. Shorthorn World 25 (19):88. December 25, 1940.

Mortality in street tree planting. By Malcolm A. McKenzie. Proc. Mass. Tree Wardens' Ann. Meeting, February 7-8, 1940.

The tree warden and the town forest. By Malcolm A. McKenzie. Proc. Fifth Ann. Conf. Current Governmental Problems, November 15-16, 1940.

Diseases of tree leaves and fruits; Diseases of woody parts of trees; Diseases of underground parts of trees. By Malcolm A. McKenzie. A Handbook of Information for Tree Wardens and City Foresters (published by Mass. Tree Wardens' Assn.) pt. IV:81-84. 1940.

The Dutch elm disease situation as it concerns Massachusetts. By A. Vincent Osmun. Transcriptions of Certain Papers presented at the Seventh Annual Five-Day Short Course for Tree Wardens and Foresters:43-45, M. S. C., March 30, 1940.

Sulfur dioxide gas damages foliage. Science News Letter 37 (2):184. March 23, 1940.

How can the small milk producer meet pasteurization requirements? By J. H. Frandsen. Sixth Ann. Year Book, Mass. Milk Inspectors' Assoc. 1940.

Quality goat's milk and how it is produced. By J. H. Frandsen. Dairy Goat Jour. March, 1940.

Sanitary aspects of packaging milk and milk products. By M. J. Mack et al. Amer. Jour. Pub. Health Yearbook Supplement to Vol. 30, No. 2, February 1940.

The use of corn syrup solids in ice cream and ices. By L. R. Glazier and M. J. Mack. Proc. 40th Ann. Conv. Internatl. Assoc. Ice Cream Mfrs., October 1940.

Suggested standards for chocolate milk drinks. By W. S. Mueller. Milk Plant Monthly, March 1940.

Orchard insect pests in 1939. By W. D. Whitcomb and A. I. Bourne. Mass. Fruit Growers' Assoc. Ann. Rpt. 1940:18-22.

Apple pests and their control. By A. I. Bourne, O. C. Boyd, O. C. Roberts, and W. D. Whitcomb. M. S. C. Extension Leaflet 189. 56 pp. October 1940.

Controlling the grape plume moth. By Wm. E. Tomlinson, Jr. Horticulture, April 15, 1940, page 4, New England Section.

Results of recent Massachusetts spraying experiments. By A. I. Bourne. Jour. N. H. Hort. Soc. 4 (1):20-27. 1940.

A report of a study of container costs in soda fountains. A clean service for every customer every time. By Rollin H. Barrett, Carl R. Fellers and Julius Novick. The Sanitarian 2 (12):1-13. 1940.

Facts you should know about foreign substance in food. By Carl R. Fellers. The Internatl. Steward 36 (8):8-9, 12 and 16. 1940. Hotel and Restaurant 8 (6): 14-15, 57.

New facts on the nutritive value of the cranberry. By C. R. Fellers, P. D. Isham, W. B. Esselen, and A. S. Levine. Amer. Cranberry Exchange Pamphlet. 6pp. 1940.

Food Poisoning. By C. R. Fellers. Old Farmer's Almanac No. 195, 66. 1941.

Celery—Boston Style. By Robert E. Young. Better Crops with Plant Food, August-September 1940.

Asters, the best of the Michaelmas daisies. By Ray M. Koon. House and Garden, September 1940, p. 28.

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